UNIVERSITY OF CAPE TOWN
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

ASSESSMENT OF LOCAL WATER DISTRIBUTION INFRASTRUCTRURE MANAGEMENT AND MAINTENANCE CHALLENGES

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Minor-dissertation submitted to the Faculty of Engineering and the Built Environment, in partial fulfilment of the requirements for the degree of Master of Engineering specialising in Civil Infrastructure Management and Maintenance.

DEPARTMENT OF CIVIL ENGINEERING

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DATE: JUNE 2017

DECLARATION

I know the meaning of plagiarism and I declare that all the work in this document, except for that which is properly acknowledged, is my own. It is being submitted for the degree of Master of Engineering specialising in Civil Infrastructure Management and Maintenance at the University of Cape Town. I also confirm that this work has not been submitted at any other university or academic institution for examination or any other purposes.

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ABSTRACT

Central to the South African government's vision of providing services to all is on-going maintenance of public infrastructure. Since 1994 the government focused on addressing backlogs in the provision of water services through new infrastructure investment; however it failed to make sufficient investment in the maintenance and renewal of this infrastructure (SAICE, 2006). Older infrastructure is not being renewed or refurbished as required and planned preventative maintenance on new infrastructure is inadequate (SAICE, 2006). This has been generally attributed to poor management strategies that are exacerbated by lack of skills in water services utilities and low levels of funding provisions (Mescht & Jaarsveld, 2012; FFC, 2013). The continuing poor maintenance of water distribution networks has contributed to high leakage rates in South Africa (FFC, 2013; DBSA, 2012).

To address challenges of maintenance of water distribution infrastructure a regulatory framework to guide municipalities is critical. The government approved the National Infrastructure Management Strategy (NIMS) in 2006 to support simultaneous infrastructure investment and maintenance (CIDB, 2008). One of the key thrusts of the strategy is the strengthening of the regulatory framework that governs planning and budgeting for maintenance. The literature survey of this study found that initiatives associated with the NIMS were very slow in gaining traction.

The study reviews water services infrastructure management frameworks that are based on present legislative instruments and standards for two study areas; City of Capetown and City of Johannesburg. Challenges associated with effective management of water distribution infrastructure are assessed based on established infrastructure management policies, strategies and asset management plans for each entity. For each study area leakage control strategies are the key maintenance strategy outputs associated with the implementation of the management frameworks; therefore the study reviewed sector plans and annual reports to assess challenges associated with carrying out effective maintenance.

The findings of the study show a correlation between the adoption of maintenance management strategies and the improvement of the performance of water distribution networks for both Cape Town and Johannesburg. The strategies are driven at the highest level of decision making in the municipalities as budgeting requirements are supported by the Integrated Development Plans of each study area. The maintenance allocations however remain below the international benchmark to enable the municipal entities to carry out satisfactory maintenance of their distribution infrastructure.

KEYWORDS: Water distribution infrastructure, infrastructure management, legislative frameworks, asset management, maintenance budgeting, water services

CONTENTS

GLOSSARY

AMIP	Asset Management Improvement Programme
ALC	Active Leakage Control
Capex	Capital Expenditure
CARL	Current Annual Real Losses
CBD	Central Business District
CCT	City of Cape Town
CIDB	Construction Industry Development Board
CIP	Comprehensive Infrastructure Plans
CoJ	City of Johannesburg
COGTA	Cooperative Governance and Traditional Affairs
CRC	Current Replacement Cost
CSIR	Council for Scientific and Industrial Research
DWS	Department of Water and Sanitation
ECSA	Engineering Council of South Africa
EPWP	Extended Public Works Programme
EUL	Expected Useful Life
FY	Financial Year
GDS	Growth and Development Strategy
GRAP	Generally Recognised Accounting Practices
HR	Human Resources
IDP	Infrastructure Development Plan / Integrated Development Plan
ILI	Infrastructure Leakage Index
IRC	Infrastructure Report Card
IURP	Infrastructure Upgrade and Renewal Plan
IWA	International Water Association
JW	Johannesburg Water
LGCAMG	Local Government Capital Asset Management Guideline
MFMA	Municipal Finance Management Act, 2003
MIG	Municipal Infrastructure Grant
MISA	Municipal Infrastructure Support Agent

MSA	Municipal Systems Act, 2000
NIMS	National Infrastructure Maintenance Strategy
NQF	National Qualification Framework
OGA	Operation Gcin'amanzi
PFMA	Public Finance Management Act
PI	Performance indicators
PLC	Passive Leakage Control
PRV	Pressure Reducing Valve
SANS	South African National Standard
SAICE	South African Institution of Civil Engineering
WC/WDM	Water Conservation/ Water Demand Management
WCWSS	Western Cape Water Supply System
WSA	Water Services Authority
WSDP	Water Services Development Plan
WSP	Water Services Provider

1. INTRODUCTION

1.1 Background

Substantial investment in new water services infrastructure has been made in South Africa since 1994 to address backlogs and to extend services to people who were not formally served by existing infrastructure prior to 1994 (SAICE, 2006). However, there has been insufficient resource allocation for maintenance and renewal of the existing infrastructure (SAICE, 2011). CSIR/CIDB (2007) highlighted that the poorest municipalities acquire new infrastructure without the capability to maintain both old and new. Infrastructure failures and service delivery protests are a frequent headline in the media and many South Africans experience these failures in the form of unreliable water and electricity supplies, poor public road networks, upsets and blockages in sewer networks, etc. A survey done on South Africa as part of the compilation of the World Economic Forum's 2016 Global Risks Report 2016 indicated that critical infrastructure failure is the third highest risk for economic activity in South Africa (BizNews, 2015).

In 2006, the Council for Scientific and Industrial Research (CSIR) and the Construction Industry Development Board (CIDB) published a discussion document titled *Towards a framework for the maintenance of municipal infrastructure: In support of government growth objectives* and in 2007 extracted a major portion of this report that dealt with the current municipal infrastructure challenges for publication of another report titled *The State of Municipal Infrastructure In South Africa and its Operation and Maintenance* (CSIR/CIDB, 2007). Both documents highlighted the big challenges that service delivery infrastructure in municipalities face throughout South Africa. CSIR has been doing research into performance of municipal infrastructure since 2001 and in 2006 the first South African Infrastructure Report Card (IRC) detailing the state of public infrastructure was released by the South African Institution of Civil Engineering (SAICE). Before 2006 there were no records of any formal infrastructure performance audits or studies on the state of municipal infrastructure (CSIR/CIDB, 2007). The second infrastructure report card was released in 2011 and showed a trend of the performance of infrastructure since 2006.

The SAICE IRCs use a grading system that ranks infrastructure sectors and sub-sectors as described in Table 1. The grades are assigned on the basis of condition and performance, and capacity versus demand (SAICE, 2006). The overall grade across all sectors of South Africa's built environment infrastructure was D^+ in 2006 and it improved in 2011 to an overall grade of C^- (SAICE, 2011). The 2006 SAICE IRC noted that in parts the infrastructure is very good and even world class while it's very poor in rural settings. Despite the overall improvement, 4 sub-sectors (Bulk water infrastructure, Sanitation for non-major urban and rural areas, hospitals healthcare infrastructure, and clinics healthcare infrastructure) showed further deterioration while the other sub-sectors remained unchanged or had some improvement (SAICE, 2011).

Water services infrastructure, which comprises of local treatment and distribution of water, didn't show any improvement between 2006 and 2011 for major urban areas as well as all other areas (SAICE, 2011). Areas that fall outside of the major urban areas had a D^- rating which indicates that the Infrastructure is no longer sufficient for current demand and is being poorly maintained. Failure to address this infrastructure will eventually lead to complete failure or operation of local water infrastructure on the verge of failure (E rating).

Table 1: IRC grading scale (SAICE, 2006; SAICE, 2011)

Grading	Meaning	Characteristics
A	Very Good	Infrastructure is comparable to the best internationally in every respect. It is in excellent condition and well maintained, with capacity to endure pressure from unusual events.
B	Good	Infrastructure is in good condition and properly maintained. It satisfies current demands and is sufficiently robust to deal with minor incidents.
C	Fair	Infrastructure condition is acceptable although stressed at peak periods. It will need investment in the current Medium-term Expenditure Framework period to avoid serious deficiencies.
D	Poor	Infrastructure is at risk and not coping with demand and is poorly maintained. It is likely that the public will be subjected to severe inconvenience and even danger without prompt attention.
E	Very Poor	Infrastructure has failed or is on the verge of failure, exposing the public to health and safety hazards. Immediate attention is required.

Figure 1 summarises the need for water infrastructure as determined by a study done in 2010 to determine water infrastructure needs in South Africa; it was determined that a total of R62 billion would be required for backlogs in water reticulation, bulk water, and treatment infrastructure (DBSA, 2012). The South African government has been prioritising these backlogs through government grants, but the grants only fund the creation of assets and do not cater for operational and future maintenance costs (FFC, 2013). Therefore there is a challenge of managing new and old infrastructure assets; and effective frameworks are necessary to ensure sustainability of water infrastructure.

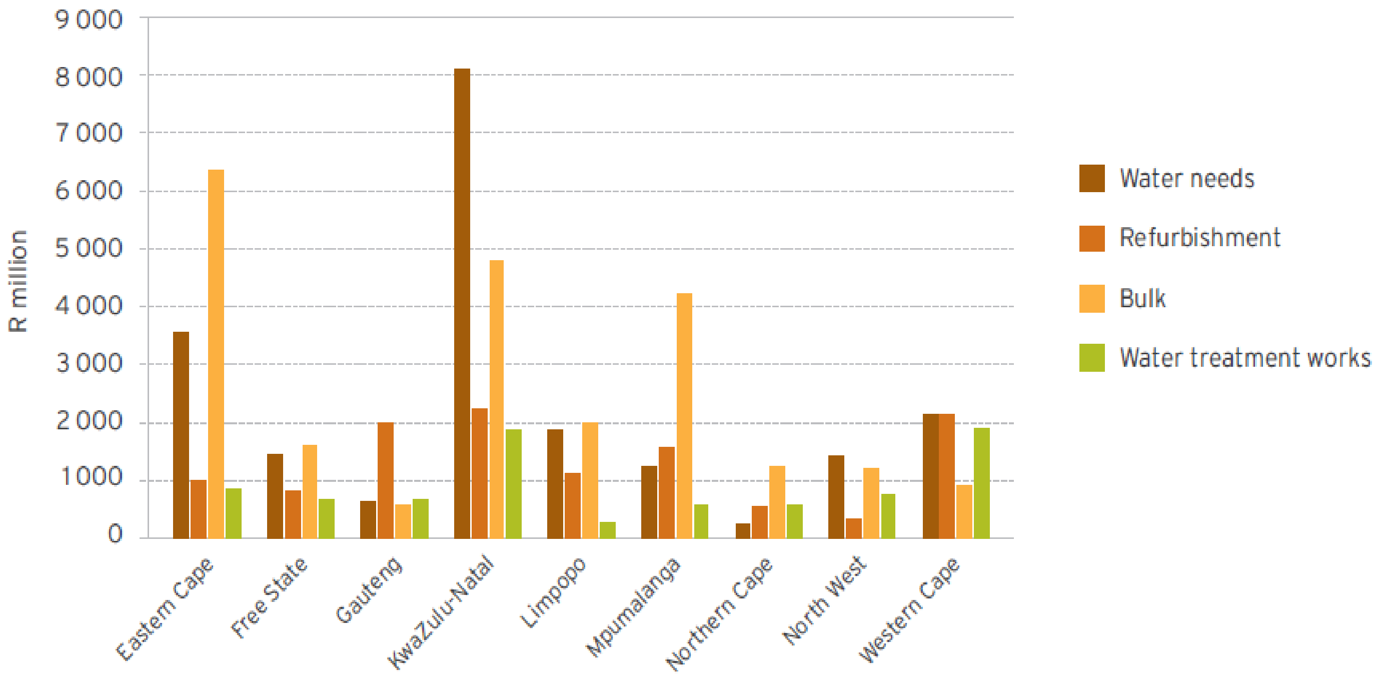


Figure 1: Total water investment needs (DBSA, 2012)

1.2 Problem statement

SAICE (2006) indicated that leakage of treated potable water in distribution networks is a major problem. There has been major efforts made in extending provision of water since 1994 and there are ongoing strides to improve the quality of water provided through various initiatives, however, the poor state of ageing local distribution pipelines as highlighted by SAICE (2006) makes the provision of water services unsustainable. The IRMSA (2016) pointed out that South Africa might be facing a looming water crisis due to shortage of water and this has been identified as one of the top ten South African country and industry level risks. Therefore there's a need to improve the management of water services infrastructure in order to efficiently use limited available water resources.

The national average of water losses from water distribution infrastructure was 35% in 2012 (DBSA, 2012). The losses consist of apparent and real losses in the municipal distribution systems and exclude losses in bulk supply mains. The apparent losses are due to water theft, inaccurate metering and administrative errors, while real losses are leaks from the system through pipelines and connections (DWA, 2013) and account for up to 24% of total water supplied (Chikwanda, 2011). A study initiated by the Water Research Commission to compare levels of leakage of 30 South African water utilities found that more than 50% of these systems have annual real losses higher than the international average of 276 litres per connection per day determined from 27 supply systems across 19 countries (Seago *et al*, 2004). In 2006 it was estimated that 27% of water supplied by Rand Water is lost in the municipal distribution system (CSIR/CIDB, 2007). Leaks on small-diameter distribution pipelines are the most common leaks municipalities encounter but large diameter pipeline leaks can lead to more prolonged and extensive losses (McKenzie, 2014).

Table 2: Water loss percentage and ILI for 8 South African Metros (DWA, 2013)

Metropolitan Municipality	Water Loss %	ILI
Johannesburg	36.5	8.3
Tswane	22.9	5.6
Ekurhuleni	31.8	5
Ethekwini	35.3	6.8
Cape Town	15.2	2.1
Nelson Mandela Bay	32.4	4.4
Buffalo City	28.9	3.5
Mangaung	35.7	6
Weighted Average	29.7	5.7

Table 2 shows leakage information of 8 Metropolitan municipalities that supply 46% of South Africa's urban water and these have an average water loss percentage of 19.7% based on data obtained at the end of 2012 (DWA, 2013). The leakages compared to a benchmark minimum value are measured by an Infrastructure Leakage Index (ILI) that ranges from 1 (best practice) up to 30 (losses 30 times the benchmark value) (Lambert *et al*, 2014). For these municipalities the average losses are on average 5.7 times the benchmark value. According to Chikwanda (2011) real losses in medium to high-income areas are as a result of complex urban networks and the cost of maintenance and refurbishment of existing infrastructure. Real losses in rural areas may be higher due to high maintenance backlogs (National Treasury, 2011).

Several reports and studies attribute the above challenges to poor institutional and legislative frameworks for management of infrastructure assets at national and local government spheres (FFC, 2013; DBSA, 2012). The overarching finding is that there is no legislation that properly addresses the full spectrum of public infrastructure asset management in line with international best practices (FFC, 2013). Current and past legislative frameworks acknowledge the need for maintenance of assets and there have been several initiatives to strengthen the regulatory frameworks governing management of infrastructure but the associated improvement in infrastructure condition has not materialised as expected as seen on the 2011 SAICE IRC.

1.3 Hypothesis

The existing regulatory framework that governs planning and budgeting for maintenance of local government infrastructure as well as maintenance guidelines are not sufficient to address maintenance challenges in the water services sector. Public infrastructure maintenance budgeting is not aligned with international best practices and therefore maintenance spending on water services infrastructure is not adequate for achievement of sustainable management of water distribution networks and reducing high levels of leakage. Municipal entities and water utilities do not have sufficient internal technical resources to implement the correct leakage control strategies that are based on knowledge of infrastructure, performance and optimal total life cycle costs.

1.4 Research significance and objectives

The study investigates challenges associated with management and maintenance of water distribution infrastructure under the current regulatory frameworks for management of infrastructure; it aims to highlight the progress that was made on targeted maintenance improvement programs that were developed over the last two decades for providing guidance to municipalities and government departments.

The benefits of effective implementation of initiatives targeted at water services infrastructure management are a drastic reduction in infrastructure life cycle costs, the reduction of water lost to groundwater and storm-water systems through distribution network leaks, and maximising the useful life of the distribution infrastructure. An understanding of the challenges prohibiting the achievement of this vision will assist municipal entities to make targeted improvements to the correct areas in the management frameworks.

The main objectives of this research include:

1. Reviewing existing water distribution management and maintenance literature including legislative framework developments with a direct or indirect impact on water services infrastructure.
2. Assessing the current state of the practice of infrastructure maintenance management for water distribution infrastructure.
3. Establishing the alignment of municipal maintenance policies with the overarching legislation governing infrastructure management and sustainability.
4. Determining the effectiveness of current regulatory frameworks.
5. Reviewing municipal budgeting and expenditure norms on water distribution network maintenance.
6. Identifying gaps in current frameworks impacting on effective maintenance of water distribution infrastructure.

1.5 Research scope and limitations

The review of the overarching legislation covers the entire local government sphere legislative frameworks that have set the tone for managing water services infrastructure. The scope of this research report is limited water distribution infrastructure that local government departments or entities are responsible for. The research methodology uses case studies to demonstrate the effectiveness of the water services legislative frameworks developed to date. Case studies were be obtained from available quantitative and qualitative data in literature through documentary analysis to test the hypothesis presented above.

1.6 Report structure

The minor-dissertation takes the form of a critical review of the state of management and maintenance of water distribution infrastructure. The hypothesis was investigated extensively through an in depth review of academic literature and published government reports. The research used a qualitative research design. The research report will be presented in five chapters as follows:

- Chapter 1 presents the background to the research and defines the research problem. It presents the hypothesis to be tested as well as the objectives of the research.
- Chapter 2 is a review of the state of infrastructure maintenance of water services infrastructure as well as legislation governing planning and budgeting for infrastructure maintenance. It presents a comprehensive review of key elements that affect efficient implementation of infrastructure maintenance as well as leakage control strategies that can be implemented to effectively manage water distribution infrastructure.
- Chapter 3 contains a brief review of research methods and presents a detailed description of the chosen research methodology for obtaining data on the implementation of present legislation for maintenance of water services infrastructure and determination of the effectiveness of the present frameworks in the local government sphere. It describes how the water services infrastructure management frameworks for the identified study areas were assessed.

- Chapter 4 presents findings and discussion of the assessment.
- Chapter 5 summarises the study and fulfilment of the research objectives and concludes the research report. The chapter also includes recommendations.

2. LITERATURE REVIEW

2.1 Infrastructure maintenance

2.1.1 What is maintenance?

Maintenance is defined as actions required for an asset to reach its expected useful life (EUL) (DPLG, 2010). The maintenance activities may be planned or unplanned. Planned Maintenance activities are measures taken to prevent known failure modes and are time or condition based. Proactive maintenance is normally justified for critical assets that may result in severe consequences in the event of a failure (DPLG, 2010). Unplanned maintenance is associated with repair actions required in the case of an unexpected partial failure or damage. An effective maintenance programme therefore requires alignment between the strategic management objectives and the operational tasks performed by an asset (Boulenouar & Schweitzer, 2015). At local government level, maintenance of infrastructure is the biggest challenge that municipalities are faced with (Kolver, 2014). Infrastructure maintenance strategies used are inadequate in relation to the asset value of public infrastructure (MISA, 2013).

CSIR/CIDB (2007) highlighted that poor design and construction as well as inappropriate operation and maintenance, has led to premature deterioration of physical infrastructure. in addition maintenance non-compliance with regards to the national water resources strategy developed in 2009 (SAICE, 2011) has compounded the deterioration of infrastructure bringing the recapitalisation timeline closer. SAICE (2006) stated that skills shortages and lack of maintenance were the key themes across all sectors that were responsible for the low condition grades of infrastructure.

2.1.2 Pro-active maintenance

The Strategic Framework for Water Services (DWA, 2003) states the following:

> *"It is essential for water services authorities to protect their assets by ensuring that an appropriate maintenance and rehabilitation plan is developed and implemented. This plan must be based on the principle of*

preventative maintenance in order to ensure that, as far as this is practical, damage to assets is prevented before it occurs. The water services authority must ensure that the maintenance and rehabilitation plan is part of the water services development plan and that this plan is implemented. Assets must be rehabilitated and/or replaced before the end of their economic life and the necessary capital funds must be allocated for this purpose."

According to Miya & Grobbelaar (2015), the current approach to maintenance of water infrastructure in South Africa is reactive and Mescht & Jaarsveld (2012) found that the culture of maintenance in small municipalities is to defer maintenance or run the infrastructure to failure. Reactive maintenance is unsustainable due to the high cost of emergency repairs due to no upfront planning or budgeting (WAMTech, 2015).

Preventative maintenance ensures that the asset achieves its EUL while poor maintenance may shorten the lifespan of infrastructure (DWAF, 2008) as illustrated in the condition curve on Figure 2. The poor maintenance regime will require rehabilitation to further restore infrastructure to its original EUL. A proper maintenance regime allows the selective rehabilitation costs to be used more efficiently to give infrastructure an extended service life before it needs to be replaced or renewed. Proactive maintenance can result in drastic reduction of life cycle costs and the ability to deliver services consistently to consumers (Mescht & Jaarsveld, 2012; Mckenzie, 2014). Pro-active maintenance however does not eliminate failures, but rather creates an environment where unexpected failures are kept to a minimum (Van Zyl, 2014).

Figure 3 illustrates the life cycle of infrastructure assets from planning to replacement or renewal with the largest proportion of the asset's life being operation and maintenance which is commonly referred to as the asset's service life (WERF, 2014). Rehabilitation at some point during the life of the asset will result in an instantaneous improvement that will increase the EUL of the asset (DWAF, 2008). During the service life the asset may undergo several rehabilitation initiatives that will always improve the condition of the asset until a point is reached where further interventions are no longer economically sustainable (WERF, 2014).

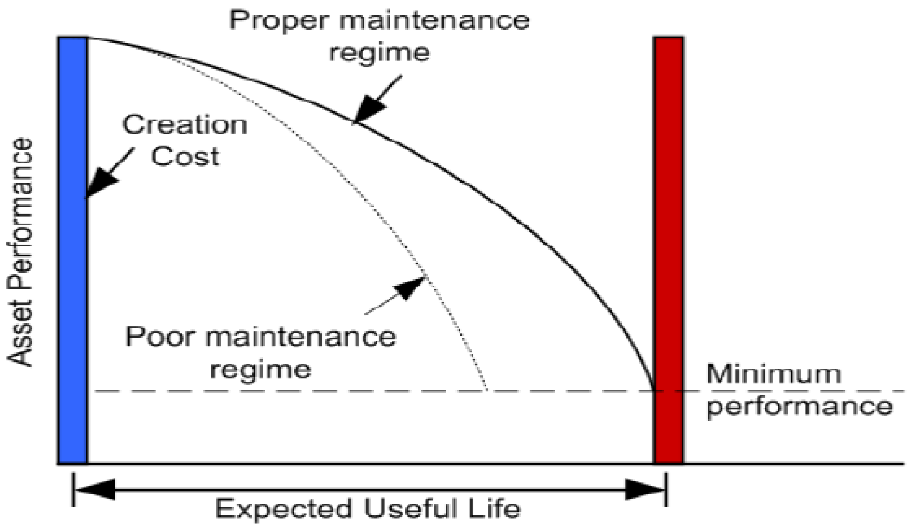


Figure 2: Infrastructure Condition Curve (DWAF, 2008)

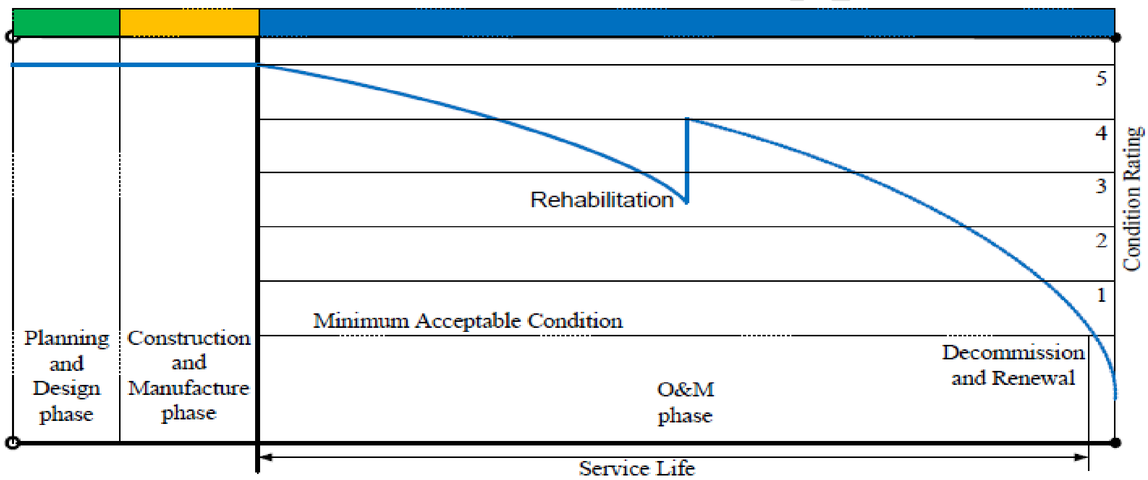


Figure 3: Total infrastructure lifecycle (WERF, 2014)

2.2 Underlying issues impairing maintenance in South Africa

CSIR/CIDB (2007) identified inadequate maintenance budgets and technical skills as the principal systemic issues underlying the problem of infrastructure maintenance in South Africa. The majority of municipalities also have shortcomings in maintenance policies and this varies across local and district government. Local and district municipalities are not prioritising operations and maintenance of infrastructure the same as metropolitan municipalities (CSIR/CIDB, 2007) and this is evident in the trends of urban water infrastructure versus those of other areas as rated by the 2006 and 2011 SAICE infrastructure report cards.

Development and implementation of asset management programmes for maintenance of water infrastructure is the main challenge limiting optimal operation and maintenance of infrastructure (DBSA, 2012). On the other hand, legislation in the past did not encourage municipalities with no understanding of the benefits of sound infrastructure maintenance (CSIR/CIDB, 2007). Data of 79 out of a total of 231 local municipalities surveyed previously by SAICE indicates that those municipalities have no suitably qualified technical staff (SAICE, 2006).

2.2.1 Budgeting constraints

A case study of a small rural municipality in the Eastern Cape Province revealed that only 1% of total operating costs were spent on repairs and maintenance in the 2011/2012 financial year (Mescht & Jaarsveld, 2012). Mescht & Jaarsveld (2012) argue that the low percentage is a reflection of the state of prioritisation of maintenance and 1% indicates a very low priority. In the same financial year, this particular municipality had a surplus of 11% of the total annual revenue while maintenance spending was just less than 1% of the revenue (Table 3).

Government grants make up the bulk of small municipality revenue including the Municipal Infrastructure Grant (MIG), which cannot be used for operations and maintenance expenditure. The new infrastructure funded by the MIG increase the future maintenance burden while there's isn't sufficient funding available for current infrastructure that must be maintained (Mescht & Jaarsveld, 2012). Value added tax (VAT) on MIG funded projects can be claimed by Municipalities, however there's no legislation that guides municipalities on where it must be spent and it ends up being spent on other expenses that may not be maintenance related (Mescht & Jaarsveld, 2012).

Table 3: Small municipality financial statement 2010/2011 (Mescht & Jaarsveld, 2012)

Income - Expenditure Statement for Financial Year 2010/11			
Revenue			
Item	**Amount**		**Percentage of total revenue**
Property rates	R	7,943,164.00	8.23%
Service charges	R	14,554,633.00	15.08%
Rental of facilities & equipment	R	157,991.00	0.16%
Income from agency services	R	1,465,002.00	1.52%
Fines	R	287,493.00	0.30%
Government grants & subsidies	R	68,754,069.00	71.25%
Other income	R	1,337,956.00	1.39%
Interest on investment income	R	1,990,845.00	2.06%
Total revenue	**R**	**96,491,153.00**	**100.00%**
Expenditure			
Item	**Amount**		**Percentage of total expenditure**
Personnel	R	20,888,317.00	24.42%
Remuneration of councillors	R	2,041,502.00	2.39%
Depreciation & amortisation	R	8,863,221.00	10.36%
Impairment loss	R	13,904,894.00	16.26%
Finance costs	R	153,700.00	0.18%
Collection costs	R	-	0.00%
Repairs and maintenance	R	931,978.00	1.09%
Bulk purchases	R	1,743,535.00	2.04%
Contracted services	R	1,538,154.00	1.80%
Grants and subsidies paid	R	26,721,068.00	31.24%
General expenses	R	8,753,328.00	10.23%
Total expenditure	**R**	**85,539,697.00**	**100.00%**
Surplus	**R**	**10,951,456.00**	

In South Africa maintenance provisions are benchmarked as a percentage of municipal operating budgets (Boshoff & Peters, 2013). According to National Treasury (2011) municipalities generally allocate 5% to 12% for repairs and maintenance. The actual percentage used differs depending on the policies of different government entities concerned (Boshoff & Peters, 2013). In the case of water services, the Department of Water and Sanitation's (DWS) blue drop asset management compliance criterion requires that 5% of the municipal operating budget be spent on maintenance of water services infrastructure (DWS, 2014a); but this funding is not linked to actual condition of infrastructure.

A recently published Maintenance Management Standard (DPW/CIDB, 2015) highlights that budgeting shall not be based on historic budget provisions or a normative allocated percentage of the total operating annual budget but should rather be based on actual maintenance objectives. FFC (2013) compared infrastructure maintenance spending in South Africa with international benchmarks and found that South African municipalities generally under budget and underspend on maintenance as illustrated on Figure 4 (FFC, 2013).

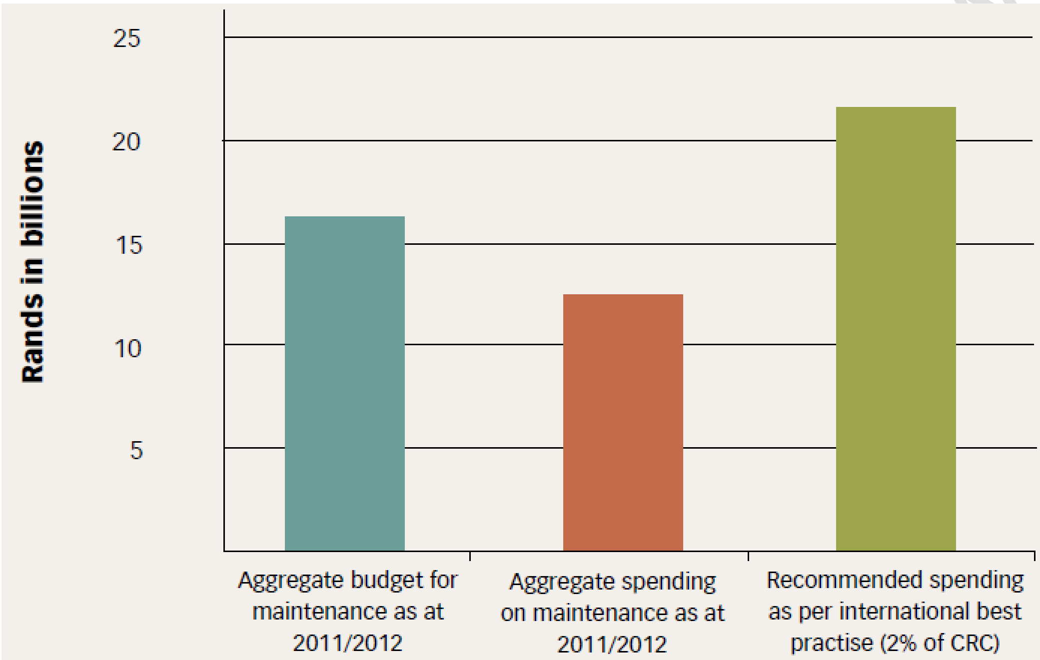


Figure 4: Budgeted Spending VS Allocation for Asset Maintenance (2011/12) (FFC, 2013)

International best practices recommend that infrastructure maintenance be costed according to the Current Replacement Cost (CRC) of physical assets with the optimum maintenance being 2% of the CRC (Boshoff & Peters, 2013). National aggregate spending and budgeting nationally falls short of this international best practice. According to FFC (2013), it was found that municipalities only spend about 80% of the budgeted maintenance expenditure; based on this observation FFC (2013) argues that increasing maintenance funding without strengthening the regulatory framework governing maintenance will add very limited value.

2.2.2 Maintenance management skills

Maintenance of infrastructure is impacted negatively in small rural municipalities by human resources issues which include the difficulty of attracting suitable technical skills or experienced professionals (Mescht & Jaarsveld, 2012). The challenge is further compounded by qualified and experienced technical managers leaving the public sector for the private sector (MISA, 2013).

According to Mescht & Jaarsveld (2012) municipalities need experienced personnel that can fill the following gaps amongst other things:

- Collection of accurate infrastructure as-built data.
- Updating of asset registers.
- Mentoring of newly appointed personnel.
- Compilation of maintenance plans and schedules.
- Budgeting for maintenance.
- Assisting technical managers with strategic infrastructure planning.

MISA (2013) states that there's a need for technical professionalism of local government officials who perform high level functions; the expectations for technical professionalism are as follows:

- Application of specialised high level knowledge, skills and competence;
- Certification by a professional body regulated by the Council for the Built Environment Act 43 of 2000;
- Continuous professional development; and
- Observation of norms, standards and ethics of the relevant built environment profession.

Vacancy rates in municipalities are as high as 90% in technical areas (MISA, 2013) and the functions and responsibility for maintenance of municipal infrastructure are not clear; there is therefore a need support municipal technical officials with a thorough understanding of infrastructure management (MISA, 2013). MISA (2013) noted that only 41% of technical managers have a degree and in 50% of municipalities the technical managers have only been in place for less than 2 years. This lack of internal resources leads to outsourcing of maintenance functions and increased municipal operating costs leading to the absence of adequate skills that can ensure quality assurance of work completed by appointed contractors (MISA, 2013).

Currently municipalities face a secondary challenge of a lot of technical officials who are unable to dispense certain duties required to deliver services due to lack of professional registration and its associated role competencies (MISA, 2013). DBSA (2012) argues that strong institutional frameworks can attract and facilitate retention of critical skills that can support good management and sustainable maintenance of infrastructure.

2.3 Local water distribution network maintenance

2.3.1 Water demand management

Water demand management consists of demand side and supply side management; in South Africa the emphasis has been placed on supply side management for many years (Hebertson & Tate, 2001) but there has being a shift in the past few years towards demand side management (McKenzie *et al*, 2007). System leakages highlighted in the problem statement for this research have a negative impact to the sustainability of demand side management.

2.3.2 Water distribution system efficiency indicators

The efficiency of water distribution systems is measured by different performance measures and the annual volume of water lost is a very important indicator of system efficiency (Hamilton *et al*, 2006). Hamilton *et al* (2006) indicates that once volumes are calculated there are other performance indicators (PIs) that must be employed to determine which losses are high or low as well as make comparison between different systems or municipalities. The main leakage indicators recommended by the International Water Association (IWA) methodology are the Current Annual Real Losses (CARL) and the

Infrastructure Leakage Index (ILI); percentage of water supplied is not recommended and is only to be used for comparison.

2.3.3 Performance categories and remedial measures

ILI can range from just over 1 for some water distribution systems in high income countries to as much as 30 for systems in low income countries (Lambert *et al*, 2014). Four performance bands were developed to classify systems with different ILI values for both developed and developing countries (Seago *et al*, 2006). These categories are A, B, C and D with two sub-divisions for each category as indicated on Table 4.

Table 4: ILI Performance Bands (Lambert et al, 2014)

Low and Middle Income Countries	**High Income Countries**	**BAND**	**General description of Real Loss Management Performance Categories** (WBI Band limits for ILI for Low and Middle Income Countries are double those for High Income Countries)
ILI range	**ILI range**		
Less than 3	**< 1.5**	**A1**	**Further loss reduction may be uneconomic unless there are shortages; careful analysis needed to identify cost-effective improvement**
3 to < 4	**1.5 to < 2**	**A2**	
4 to < 6	**2 to < 3**	**B1**	**Potential for marked improvements; consider pressure management, better active leakage control practices, and better network maintenance**
6 to < 8	**3 to < 4**	**B2**	
8 to < 12	**4 to < 6**	**C1**	**Poor leakage record; tolerable only if water is plentiful and cheap; even then, analyze level and nature of leakage and intensify leakage reduction efforts**
12 to < 16	**6 to < 8**	**C2**	
16 to < 24	**8 to <12**	**D1**	**Very inefficient use of resources; leakage reduction programs imperative and high priority**
24 or more	**12 or more**	**D2**	

From this table it is observed that developing countries are assigned double the ILI range limits compared to developed countries. For each category there are recommendations of actions (Table 5) that water utilities need to take to address system inefficiencies based on the ILI of each system (Lambert *et al,* 2014). In addition to these recommendations; the leakage management specialists for water utilities need to identify the key problem areas in the system before establishing the most appropriate interventions based on strategic objectives and available budget (Seago *et al*, 2006).

Table 5: Recommendations for Appropriate Actions for ILI Bands (Lambert et al, 2014)

WBI Recommendations for BANDS	A	B	C	D
Investigate pressure management options	Yes	Yes	Yes	
Investigate speed and quality of repairs	Yes	Yes	Yes	
Check economic intervention frequency	Yes	Yes		
Introduce/improve active leakage control	Yes	Yes	Yes	
Identify options for improved maintenance		Yes	Yes	
Assess Economic Leakage Level	Yes	Yes		
Review burst frequencies		Yes	Yes	
Review asset management policy		Yes	Yes	Yes
Deal with deficiencies in manpower, training and communications			Yes	Yes
5-year plan to achieve next lowest band			Yes	Yes
Fundamental peer review of all activities				Yes

2.3.4 Maintenance prioritisation using Infrastructure leakage Index

South Africa is one of the leading promoters of the use of the ILI as the main indicator for comparing levels of leakage amongst public water utilities (Seago *et al*, 2006). Based on the performance bands discussed in section 2.3.3, this puts South African utilities in the B1 band and there is opportunity to improve maintenance practices and active leakage management. It is recognised that the data sets across the utilities in the country will have outliers that are above an ILI of 10. Systems with ILIs above 10 are considered to be very poor and require attention; therefore in South Africa ILI values are used as a relatively rough indicator to prioritise areas with the highest leakage within the limit of available constrained budgets for leakage reduction (Seago *et al*, 2006).

2.3.5 Leakage control strategies

The implementation of effective distribution management measures can reduce water losses to an estimated figure of 11% in South Africa from a national average of 24% (DWAF, 2004; Chikwanda, 2011). This can be achieved through correct maintenance measures of the local distribution network (DWAF, 2004). The recommended international benchmark for water losses is 10% and the following thresholds can be used to guide appropriate actions to be taken (Sharma, 2008):

1. Water loss below 10%: Acceptable; but requires monitoring and control
2. Water loss between 10 to 25%: Intermediate; but can be reduced
3. Water loss above 25%: Interventions required to reduce water losses

The common misconception globally is that leak reduction can only be achieved by detection and repairs (McKenzie, 2014); however there are several additional strategies to decrease distribution systems leaks (DWAF, 2004; Charalambous *et al*, 2014):

1. Leak detection and repair
2. Pressure management
3. Effective zoning of the distribution system
4. Speed and quality of repair of visible and reported leaks
5. Pipe replacement / rehabilitation
6. Cathodic protection of pipelines

Figure 5 illustrates the effect of pro-active maintenance strategies on expected asset life of water distribution infrastructure.

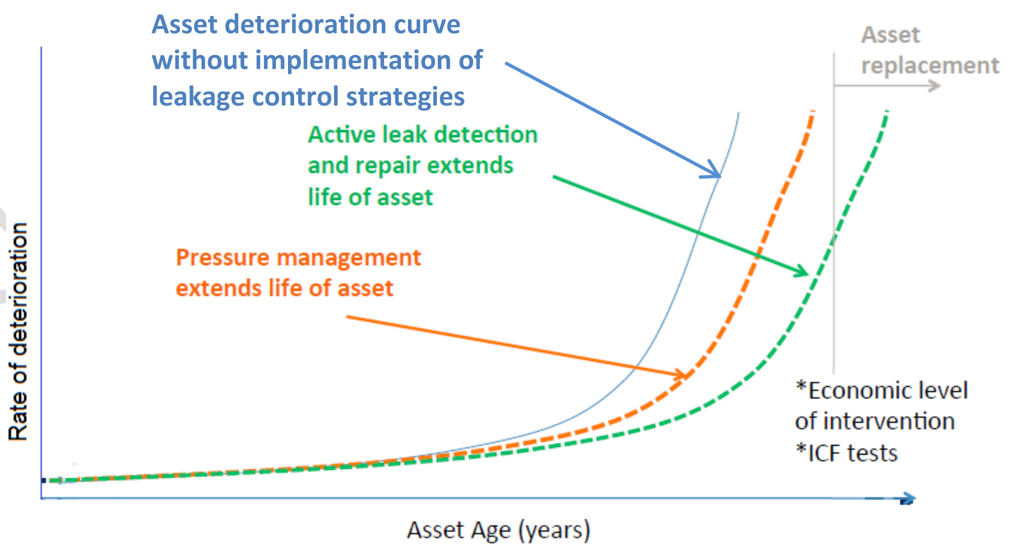


Figure 5: Effect of pro-active maintenance strategies on expected asset life (UCT, 2016)

2.3.5.1. Leak repairs

Leak repair strategies consist of Passive Leakage Control (PLC), which is reactive leak repairs of visible or reported leaks and repair of leaks identified through Active Leakage Control (ALC) (McKenzie, 2014). Van Zyl (2014) suggests that information on pipe repairs is to be gathered to capture the type and root causes of failures, and the condition of the pipeline at the time of failure. Data from previous failures and repairs as well as current observed performance forms part of condition monitoring of water distribution pipelines (Van Zyl, 2014).

Characteristics associated with reactive leak repair strategies include: leak and burst reporting; reaction time monitoring; and leaking valve maintenance (UCT, 2016). The Regulations under Section 9 of the Water Services Act (No. 108 of 1997) of South Africa; *Norms and Standards for Quality Water Services* (DWAF, 2002) prescribe that any visible or reported burst should be repaired within 48 hours of being reported. However, reaction times below 24 hours are considered more cost-efficient (McKenzie, 2014). McKenzie (2014) highlights that this reaction time doesn't allow any time sufficient time to assess the network because it aims to minimise water losses immediately. Consequently leak repairs may be ineffective if the system pressures exceed design limits and if the network is no longer viable. According to Wegelin (2015) the potential water loss savings from improved speed and quality of repairs is difficult to predict without a detailed analysis; therefore water utilities need to assess if speed and quality of repairs can be improved.

Leaks detected by ALC are found on distribution mains and connections but on mains they can be significantly higher and range from around 2m^3/hour to 1000m^3/hour (McKenzie, 2014). ALC identifies and quantifies leaks by conducting leak detection surveys and regular intervals or when flow and pressure data indicates a need for the surveys (The intervals of ALC in South Africa for cost effective leakage detection is at 6, 12 or 24 months (McKenzie, 2014). These intervals take several factors into account which include the rate of leakage, the duration over the leakage will continue, the cost of water lost and the costs of implementation (Charalambous *et al*, 2014).

ALC is based on locating positions of leaks on distribution pipelines by using leakage detection equipment; this strategy is deployed in areas where leakage is not visible but has high leakage rates based on recorded excessive minimum night flows (Charalambous *et al*, 2014). ALC assists in determining the small leaks before they become visible bursts; however it is noted that normal leak detection equipment can detect leaks above 250 litres/hour and any leaks below this value are not considered cost effective to locate and repair (McKenzie, 2014). The challenge with this is that leaks that are not visible often do not cause widespread disruptions to the network and may continue for longer periods and result in larger volume losses compared to visible burst prioritised and repaired with 24 hours.

Whether repairs are based on ALC or PLC, the repair quality is a key factor to be monitored to ensure the sustainability of pipe repairs. Success factors that water utilities must incorporate in repair policies to achieve this are as follows (Charalambous *et al*, 2014):

- Efficient organisational capacity and procedures from action repairs from identification of leak through to completion of repair
- Availability of equipment and repair materials
- Sufficient funding
- Appropriate standards for materials and workmanship to drive efficient quality control (QC)

2.3.5.2. Pressure management and zoning

According to McKenzie (2014) the repair of visible leaks increases pressure in a network and this can lead to the manifestation of new leaks elsewhere in the pipeline. Therefore in conjunction with leak repairs, the distribution network's pressure parameters should be assessed to determine if excessive pressure is the main issue contributing to leaks and therefore manage it accordingly (Charalambous *et al*, 2014). Pressure management does not eliminate or repair leaks; it merely reduces and controls the flow rate of the leaks (Lambert *et al*, 2013). If successfully implemented, some leakage rates could be reduced to less than 250 litres per hour; in turn making them no longer viable leaks to locate and repair. The typical relationship between leaks and pressure reduction is highlighted in Lambert *et al*

(2013); the percentage reduction in burst frequency was noted to be 40% more than the percentage of average pressure reduction done on water mains. Figure 6 depicts an example of a pipeline operating under low and high pressure conditions.

Figure 6: Pipeline leak at low and high pressure respectively (McKenzie, 2014)

In South Africa many systems are operated at high pressures making pressure management one of the most effective leak control strategies (McKenzie, 2014). It must however be noted that due to topography and distance from supply points, the high pressure areas may be isolated (UCT, 2016). Zoning of the distribution network can be used to isolate these areas. Zoning is the process of dividing a big distribution area into smaller areas in order to measure and monitor water losses in each zone separately (McKenzie, 2014). If the high pressure areas correspond to the excessive leakage rates, pressure management becomes the appropriate leakage control strategy for the zone.

2.3.5.3. Pipeline replacement and rehabilitation

While leak repairs are effective in restoring system integrity of water mains; repairs will reach a point where they are impractical and replacement or rehabilitation is needed (McKenzie, 2014). According to DWAF (2004) the accepted practice is to replace water distribution pipelines every 50 years. But this norm overlooks the fact that different pipe materials behave differently over their service life and there may be other environmental factors (ground movement, temperature changes, etc) and operational factors (high system pressures) that can reduce the expected service life of pipes. This also means that mains that still have many years of EUL may be replaced prematurely (Boulos, 2017).

Table 6: Burst frequencies in different countries (no/100km/year) (Pearson et al, 2005)

Pipe Material	UK	Canada	Australia	Bulgaria
AC	11.5	7.3	8.4	141
Cast Iron	20.4	39.0	22.3	101
Ductile Iron	4.7	9.7	1.6	
PVC	9.4	1.2	9.0	
Steel	12.5		9.8	93

Table 6 compares burst frequencies of different pipes across different countries and significant variances in performance of pipe material can be seen. There's a correlation between burst frequencies and EUL of pipelines; and systems with high burst frequencies require replacement sooner than those with low burst frequencies (Pearson *et al*, 2005). The history of repairs and bursts frequency information is therefore crucial in justifying earlier or deferred replacements of pipes. Shand (2013) recommends integration of pipeline replacement with the reconstruction of roads in restricted areas like city centres and busy main roads. But the performance variability and deterioration of water pipes differs from that of roads; therefore the rehabilitation windows of the two assets may not be aligned.

Similar to leak repairs, before mains are replaced or rehabilitated the system pressure must be assessed and reduced where pressure is found to be excessive (Shepherd, 2013; Charalambous *et al*, 2014). Lambert *et al* (2013) highlights that pressure management can assist the water utility or municipality to defer pipe replacement if pressure management improves the performance of the distribution system. The eThekwini mains replacement program that started in 2007 replaced 12% of the total water network; after the tie-in of the new pipes a sharp increase in service connection leaks was seen (Figure 7). Replacement of pipeline is the most expensive of the leakage control strategies and it is recommended that this be implemented only as a last resort where repairs are no longer feasible and pressure management options have already been explored (McKenzie, 2014).

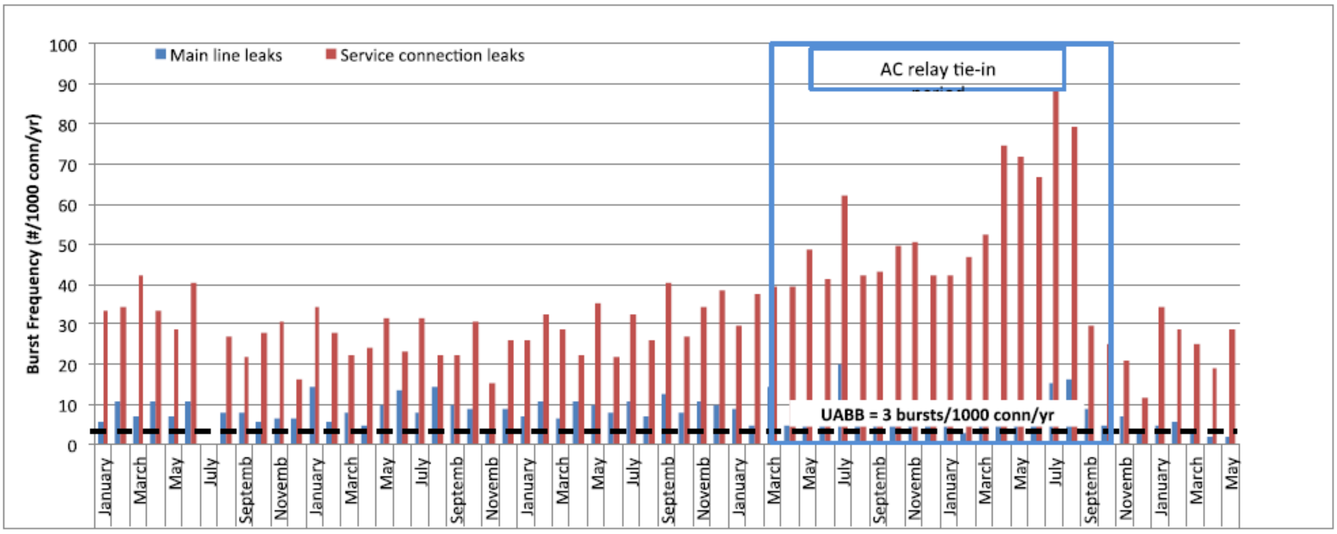


Figure 7: eThekwini burst frequencies (Shepherd, 2013)

An important question that municipalities are faced with is when is the best time to stop all the other interventions and opt for replacement. Boulos (2017) identified two alternatives that need to be compared in order to have a business case that supports replacement of a segment of a pipeline:

1) The capital cost of replacing mains combined with the future marginal operations and maintenance (O&M) costs of the new or rehabilitated pipeline; and
2) Increasing operations and maintenance costs of existing ageing pipeline.

Therefore the cost of ownership (current leak repairs, ALC, pressure management, etc) justifies the replacement of a water pipeline when it exceeds the cost of ownership (capital, pro-active corrosion protection, etc) of a new pipeline (Figure 8). The optimal point does not necessarily coincide with the end of the design life but rather with the end of the economic life of the pipeline where the cost of ownership/expected lifecycle cost is the lowest (Figure 9); after this point the cost of maintenance accelerates with an increase in failure risk cost and a decline in service provision to levels above the cost of new infrastructure. Figure 9 illustrates this point by comparing the cost of rehabilitation at point A versus 4-5 times the cost at Point B after a very short period.

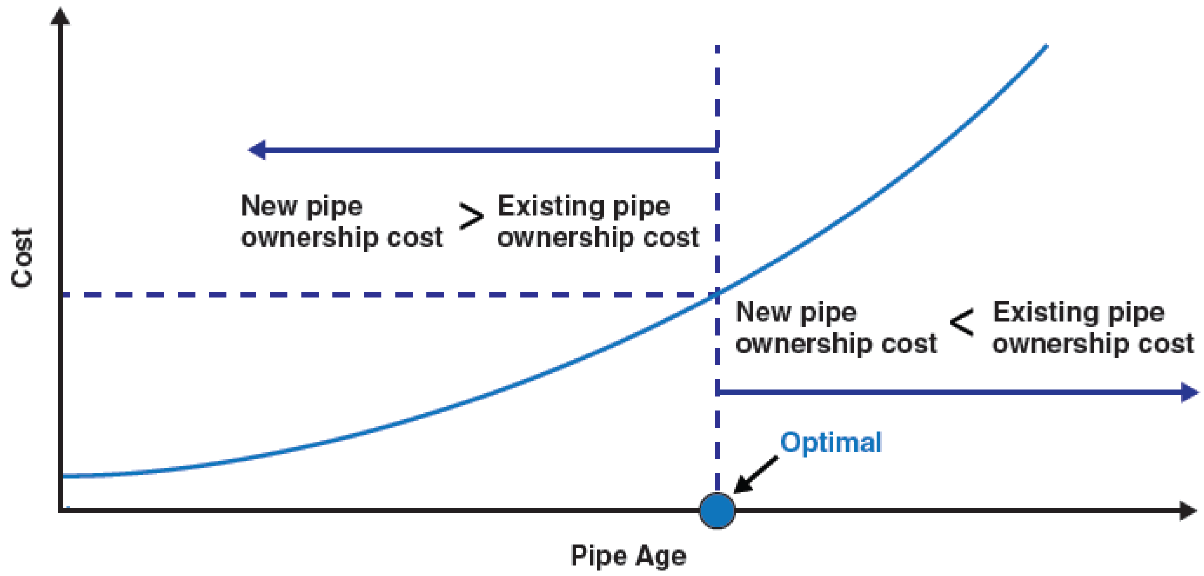


Figure 8: Optimal timing of pipeline repalcement (Buolos, 2017)

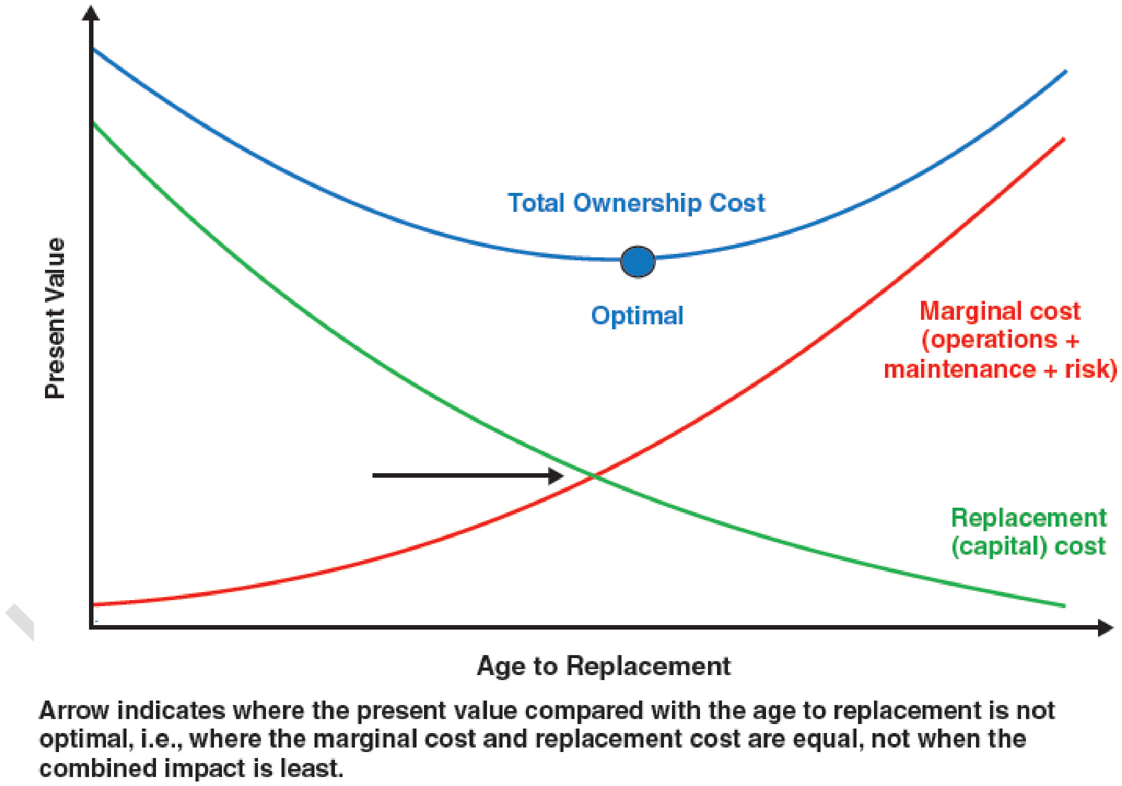


Figure 9: Pipeline total ownership cost (Buolos, 2017)

Pipes do not deteriorate in a straight line (Figure 10); as a pipe ages and deteriorates, the likelihood of failure increases and the associated cost of repairs also increases exponentially based on different factors (EPA, 2002). Some of these factors include pipe material, soil conditions and quality of water (EPA, 2002). Therefore probabilistic pipe-deterioration condition curves based on existing pipe condition inspection and historical failure rates data can be used to make risk-based decisions for selecting the right mains for replacement at the optimal time (Boulos, 2017).

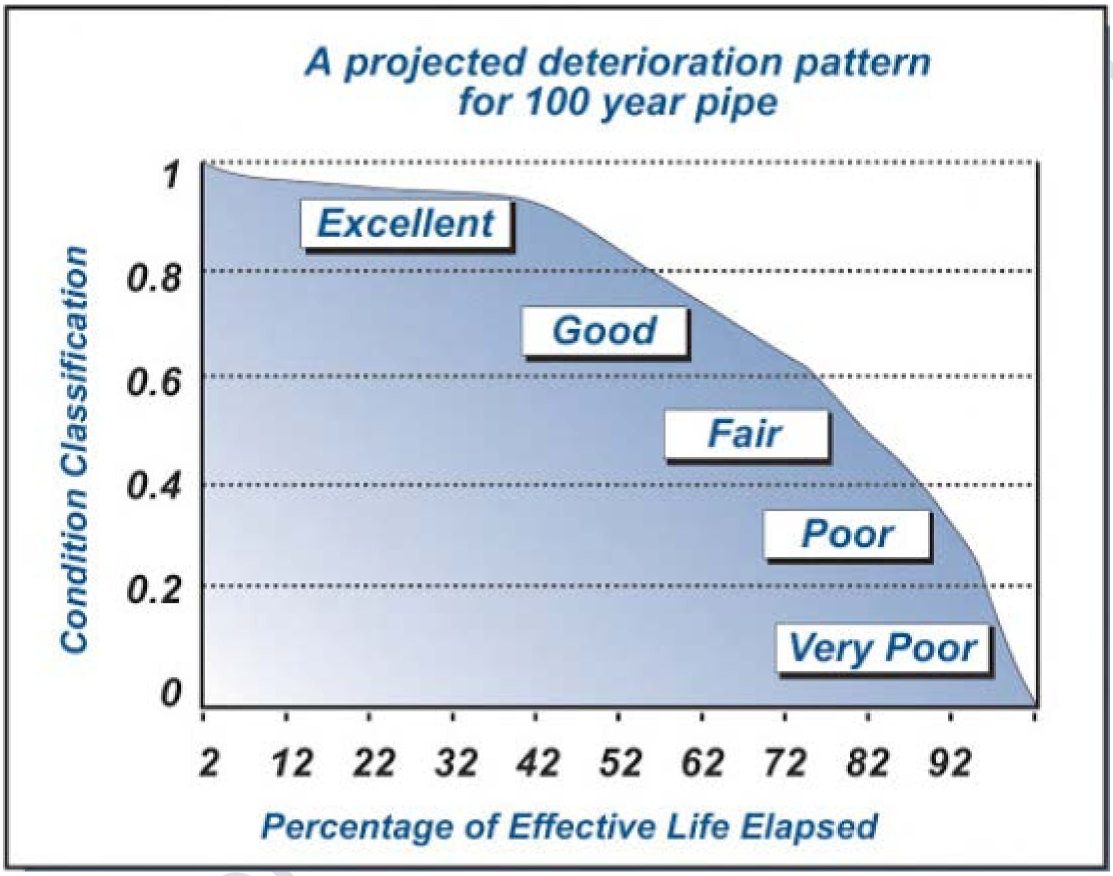


Figure 10: Typical Pipe Deterioration Curve (EPA, 2002)

2.3.5.4. Corrosion control

Corrosion control is a form of preventative maintenance that is implemented on distribution pipelines where there's a risk of corrosion to ensure that failure does not take place as a result of material deterioration. Metal water distribution pipes typically form an anode and in the presence of a galvanic cell formed in the surrounding saturated soils leading to galvanic corrosion damage over time (Van Zyl, 2014). Stray electrical currents from other systems travelling through water pipes can cause electrolytic corrosion damage where the current leaves the metal pipes. These forms of corrosion lead to pipe degradation in the form of pitting through the walls of the pipe and eventually failure of the pipe where pitting corrosion has taken place (Rand Water, 2013). For concrete pipes chloride attack on concrete in chloride rich soils may expose reinforcing steel wires to corrosive agents.

Methods of corrosion control include selection of suitable materials versus corrosive agents or environment, application of protective internal or external linings and coatings and protecting pipelines from stray currents by cathodic protection (Van Zyl, 2014). The installation of a cathodic protection system is informed by "Cathodic Protection and Corrosive surveys" (Rand Water, 2013). Corrosion control however doesn't end with the installation of the cathodic protection system; cathodic protection is one of the aspects that need monitoring to ensure that problems in the distribution pipeline are identified early (Van Zyl, 2014).

Table 7: Proportion of water Distribution pipe materials in South Africa

Pipe Material	Percentage (%)
Polyvinyl Chloride-PVC	25
Asbestos Cement-AC	21
Asbestos	19
Unplasticised Polyvinyl Chloride-uPVC	16
Steel	8
Cement	4
Bitumen coated	3
High Density Polyethylene-HDPE	2
Copper	1
Galvanised mild steel	1
Mortar lined steel	1
Cast iron	1

Pipe materials susceptible to corrosion are mainly metal pipes but a survey done by Momba & Makala (2004) showed that metal pipes are not used extensively in South Africa in comparison to PVC and Asbestos Cement pipes (Table 7). Unplasticised Polyvinyl Chloride (uPVC), High Density Polyethylene (HDPE) and Glass-reinforced plastic (GRP) pipes are not subject to corrosion but the steel joints and fittings at valve chambers require internal and external corrosion protection usually by using epoxy based coatings to protect the integrity of the pipeline (Shand, 2013).

2.4 Infrastructure Maintenance Legislative Framework Developments

2.4.1 Over-arching legislation

A municipality's functions and powers are assigned to it in terms of the Constitution of the Republic of South Africa (RSA, 1996). Figure 11 indicates the local government legislation suite that municipal entities exercise their legislative duties and rights against (DLPG, 2010). The Municipal Finance Management Act (MFMA) and the Municipal Systems Act are the two main pieces of legislation that provide for the safeguarding of local government infrastructure.

National Treasury is responsible for national, provincial and municipal budgets in terms sections 215-216 of the Constitution of South Africa (RSA, 1996; RSA, 2004). For local governments the provincial treasury is required to assist the National Treasury in enforcing compliance with the measures established in terms of the said constitution including those established in terms of the MFMA (RSA, 2004). The Member of the provincial Executive Committee (MEC) for finance is the head of the provincial treasury (RSA, 2004) and therefore the custodian responsible for ensuring compliance with the MFMA by the municipal council at the constitutional level.

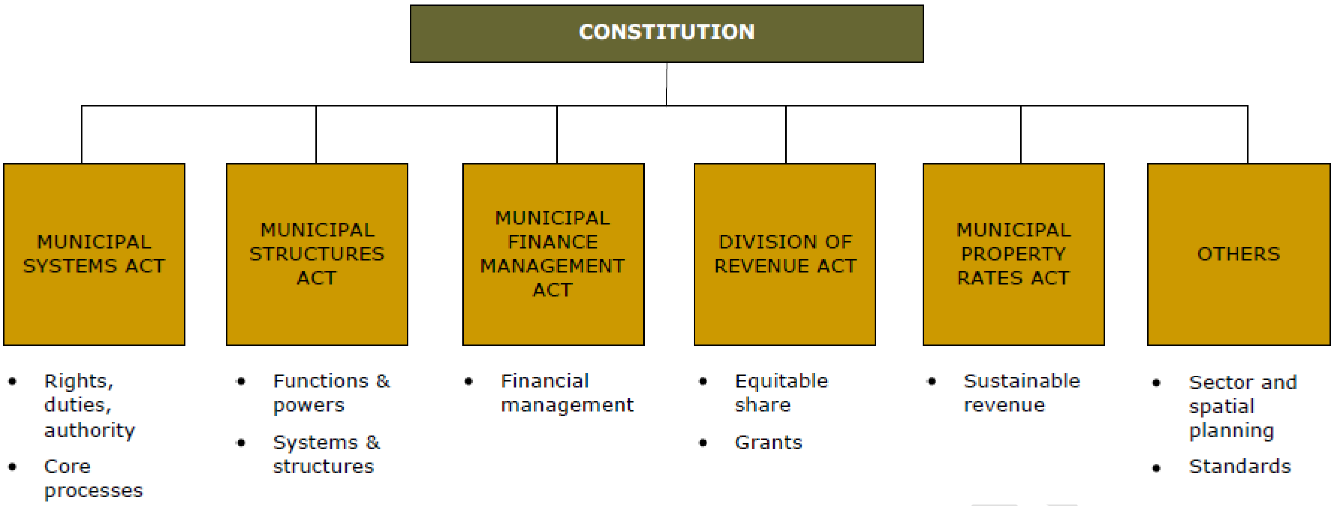


Figure 11: Local Government legislation (DPLG, 2010)

2.4.1.1. General responsibilities and reporting structures

The Constitution of the Republic of South Africa recognises a municipal council established in terms of section 55 of the Municipal Structures Act as the highest authority in a municipality (IMFO, 2009; RSA, 2004). The MFMA enforces this recognition by vesting the council with the executive leadership. Therefore the duties of the council are to monitor the administration of the municipality by approving annual budgets, providing oversight and developing policies (IMFO, 2009; SALGA; 2011). In terms of section 239 of the Constitution of the Republic of South Africa the Municipal Council is recognised as an organ of state (RSA, 1996). SALGA (2011) states the following: “a council delegates its executive authority to the executive mayor of committee, but does not delegate its legislative powers. The council retains the powers to approve policy and budgets and to exercise oversight over the mayor in the implementation of policy, budgets and by-laws.”

The implementation of the policies takes place at an administrative level and it is the duty of the Municipal Manager to form and develop an economical and accountable administration (RSA, 2004). Furthermore, the Municipal Manager as the accounting officer of the municipality is responsible and accountable for compliance with the MFMA. The failure to comply with any of the responsibilities of the accounting officer in terms of the MFMA must be reported by Municipal Manager to the Executive Mayor as well as the MEC responsible for finance (RSA, 2004).

According to SALGA (2011) the Municipal Manager reports to the Executive Mayor but is accountable to the Municipal Council. The Executive Mayor is the executive leader of the municipality (RSA, 1998). This role also monitors budgetary control, early identification of financial challenge and reports back to the MEC (IMFO, 2009). However, where the council fails to adopt or implement a budget-related policy or there's any non-compliance by a political structure or office-bearer of the municipality the, Municipal Manager is required to inform the MEC in writing (RSA, 2004).

The tactical and operational functions of the Municipality are the responsibility of Senior Managers appointed in terms of section 56 of the MFMA; Senior Managers are directly accountable to the Municipal Manager and are required to perform their functions subject to the directions of the Municipal Manager (RSA, 2004). The Executive Mayor may monitor the operational functions of the municipality but may not interfere in the performance of the functions (RSA, 2000).

2.4.1.2. Non-compliance with legislation

Contravention or failure to comply with a provision of by-laws of a municipality and other legislation that is administered by a municipality may lead to institution of criminal proceedings and prosecution by a staff of the municipality who is authorised in terms of the National Prosecuting Authority Act (RSA, 2004).

According to RSA (2003) the MEC for finance may intervene in terms of the appropriate provisions of section 139 of the Constitution if a municipality fails to comply with the budgeting provisions of the MFMA, including taking into account the municipality's integrated development plan when preparing the annual budget. The provincial treasury executive may dissolve the Municipal Council in exceptional circumstance and appoint an administrator until a new council is elected (RSA, 1996).

2.4.1.3. Municipal Finance Management and Municipal Systems Acts

According to DBE (2010) asset management and maintenance represents a unique set of challenges for local government, and therefore the Municipal Systems Act of 2000 and Municipal Finance Management Act (MFMA) of 2003 where developed to address these challenges (DBE, 2010). Section 4(2) (d) of the Municipal Systems Act requires municipalities to provide municipal services in a financially sustainable manner. It defines financial sustainability as the provision of municipal services in a manner that ensures that the financing and budgeting covers the lifecycle costs of providing the service.

Municipal Systems Act prescribes the process for establishing an Integrated Development Plan (IDP) in terms of which all services are to be delivered (Hollingworth *et al*, 2011). The Act defines the IDP as the principal strategic planning mechanisms that inform all decisions related to provision of these services. Section 63 (1) of MFMA delineates specific duties with respect to the management of municipal assets and requires financial officers to safeguard and maintain infrastructure assets (RSA, 2000).

In order to conform to the requirements of these acts municipalities should plan and provide for the long term management of all their infrastructure assets (Wall, 2004). Municipalities are not supposed to fund any projects that are not captured on the IDP (Hollingworth *et al*, 2011). An earlier study had found that these plans were generally not supported by sound analysis of infrastructure needs (Wall, 2004).

2.4.1.4. Generally Accepted Municipal Accounting Practice standards

Generally Accepted Municipal Accounting Practice standards (GAMAP) standards were introduced in 1999, as prescribed by the Public Finance Management Act of 1999, and later revised in 2004. The implementation of the GAMAP is aligned with the implementation of the MFMA (ASB, 2004).

GAMAP consists of several standards that municipalities need to comply with based on the different classes of municipal assets. Municipalities are required to compile GAMAP compliant asset registers for movable, property, and infrastructure assets (RSA, 1999). Paragraph 61 Of GAMAP 17 recognises that repairs and maintenance policies can affect the useful life of an asset by either increasing the useful life of assets or resulting in poor maintenance or indefinite deferment due to budgetary constraints. This performance trait of water distribution pipelines was discussed in section 2.3.5.3.

2.4.1.5. Generally Recognised Accounting Practice

RSA (2003) requires municipal financial statements to be based on Standards of Generally Recognised Accounting Practice (GRAP), some of which were not immediately available. GAMAP standards constituted GRAP for municipalities and were an interim solution until GRAP standards were issued (ASB, 2004). In conjunction with the MFMA, the GAMAP standards were expected to intensify the attention of asset management planning (Stephenson *et al*, 2000).

As indicated in the Preface to Standards of GAMAP (ASB, 2004), the equivalent Standard of GAMAP would be superseded once a Standard of GRAP was made available. In 2014, GRAP 17 came into effect and some of the major differences from GAMAP 17 were as follows:

- GRAP 17 paragraph 61 requires an annual review of the expected remaining useful lives of all significant items of PPE;
- GRAP 17 paragraph 61 requires an annual review of the expected remaining useful lives of all significant items of PPE, whereas GAMAP 17 paragraph 69 only required a periodic review if expectations deemed to be significantly different from previous estimates;
- GRAP 17 paragraph 72 also requires an annual review of the depreciation method while GAMAP 17 only required a periodic review in terms of paragraph 62 if there had been a significant change in the expected pattern of economic benefits or service potential from those infrastructure assets;
- GRAP 17 paragraph 65 requires that depreciation should not cease during idle time of assets or low production periods.

An earlier guideline to implementation of GRAP 17 stated that infrastructure assets are typically long-life assets that need to be re-valued on a regular basis when accounting standards are updated, as depreciation is not an appropriate measure of the deterioration of long-life infrastructure assets (Boyzen & Fourie, 2010). Paragraph 61 requires municipal entities to undertake condition assessments to check if the useful life has changed. Paragraph 62 further advises that in assessing whether the condition of an asset has improved or deteriorated, a thorough assessment of the useful life shall only be carried out if the deterioration is above expected normal deterioration due to ageing of the infrastructure.

The Accounting Standards Board (ASB) initiated a post implementation review of GRAP 17 in 2014 (ASB, 2015). As a result an amendment regarding condition assessments specifically was identified as part of the post-implementation review; the ASB noted that undertaking a detailed assessment of the useful lives of assets annually was too intensive and suggested that an indicator-based assessment may provide similar outcomes of the requirements of the Standard. The key difference from the original requirement is that entities would not be required to review the useful lives of assets every year, but only when specific circumstances arise and are different from the previous year. According to Boyzen & Fourie (2010), international experience indicated that it could take up to eight years to comply with GRAP 17 requirements.

2.4.2 National Infrastructure Management Strategy

The legislation discussed in sections 2.4.1 set a scene for management of infrastructure, however it set broad parameters and these were not enough to compel institutions to perform adequate maintenance of their infrastructure assets (Wall, 2004). The legislation differs from each other and makes regulatory and standards compliance in asset management difficult (Boyzen & Fourie 2010). One of the emerging issues that was identified by National Treasury with regards to infrastructure maintenance was the strengthening of the regulatory framework governing planning and budgeting (Mncwango, 2010).

About 10 years after the promulgation of the Municipal Systems Act there were still no adequate set of guidelines and strategies that support asset management at the local government sphere and this was undermining the performance of the legislation (DBE, 2010). Maintenance practises were also found to be different across different spheres of government and for the purpose of distinguishing the public sector institutions two categories were identified based on their state of maintenance as per Table 8 below. Category B institutions are those that were not paying sufficient attention to the maintenance of the infrastructure they are responsible for (CIDB, 2007). Category B institutions are comprised mainly of Municipalities that were not able to develop their maintenance policies and practices without guidance and direction from national government (CIDB, 2008).

Table 8: Maintenance Practices Category A and B Institutions (CIDB, 2007)

Category	Description	Institutions
A	Adequate and/or improving maintenance practices	SANRAL, National Government public buildings, ESKOM, TELKOM, TRANSNET, some provincial roads, some provincial health and education institutions, some well-resourced municipalities and some water boards.
B	Inadequate maintenance and/or deteriorating infrastructure	Some provincial roads, some provincial health and education institutions, majority of municipalities and some water boards.

In 2006 the government approved the National Infrastructure Management Strategy (NIMS) to promote sound maintenance of infrastructure. Its aim was to provide implementation framework for the PFMA, MFMA and Municipal Systems Act (CIDB, 2008). Although it was meant to set parameters across local government; its target was the Category B institutions. One of the four thrusts of the NIMS was the strengthening of the regulatory framework that governs planning and budgeting for maintenance. According to Wall (2008) this would result in improved motivations for setting aside increased maintenance funding. Two initiatives were identified to provide a government-wide policy framework for the management of assets (CIDB, 2007):

- Implementation of the Government Immovable Assets Act (GIAMA)
- Development of National Treasury Guidelines for Asset Management.

The second thrust of the NIMS was to assist institutions with non-financial resources. This was aimed at improving human resource capacity in institutions. One of the supportive interventions identified to achieve this was the development of norms and standards for maintenance of different types of infrastructure (CIDB, 2007).

2.4.2.1. Government Immovable Asset Management Act

In 2005 the Government-wide Immovable Asset Management Policy was approved by Cabinet and two years later, the Government Immovable Asset Management Act (GIAMA) was promulgated. The promulgation of GIAMA placed additional legal responsibilities on government entities regarding asset in their custodianship (Sable, 2016). These responsibilities include:

- The creation of verifiable asset registers.
- Documented condition assessments of infrastructure including associated maintenance costs.
- Preparation and annual revisions of immovable asset management plans.

GIAMA was however only applicable to National and Provincial Government, but to overcome the shortcomings of the local municipality IDPs it was necessary to extend GIAMA to local government. However, to date the principles of GIAMA have still not been extended for application in local governments (PMG, 2014).

2.4.2.2. Treasury Guidelines

The Local Government Capital Asset Management Guideline (LGCAMG) was issued in 2008 to provide practical assistance to municipal entities for management of public assets based on the MFMA and GRAP (National Treasury, 2008). The guideline proposed a structure of an

Asset Management Steering Committee that could guide and drive required changes and provide oversight of the implementation. The strategy presented was an integrated approach to asset management that required formulating an asset management strategy with detailed plans for acquisitions and replacements, operation and maintenance over the full asset life cycle.

Knowledge of life cycle cost is a legislative requirement in terms of MFMA and Municipal Systems Act, therefore the LGCAMG provides for the analysis of these life-cycle costs. Operation and maintenance costs in the life-cycle costing include capital and current cost related to rehabilitation while the Asset Management Framework discussed above didn't take this approach. The guideline sets out requirements for development of operation and maintenance policies and plans.

The policies and plans define the approaches to be used, and what needs to be done, to optimise performance and asset life and they also give effect to the municipal asset policy (National Treasury, 2008). A planned approach to maintenance is presented and the guideline recognises that planning for asset maintenance enables targeted action to be taken in a timely and cost-effective manner. The maintenance policies need to also include unplanned maintenance as illustrated by Figure 12. This approach ties up with the life-cycle costing of operation and maintenance costs that accounts for both rehabilitation and refurbishment.

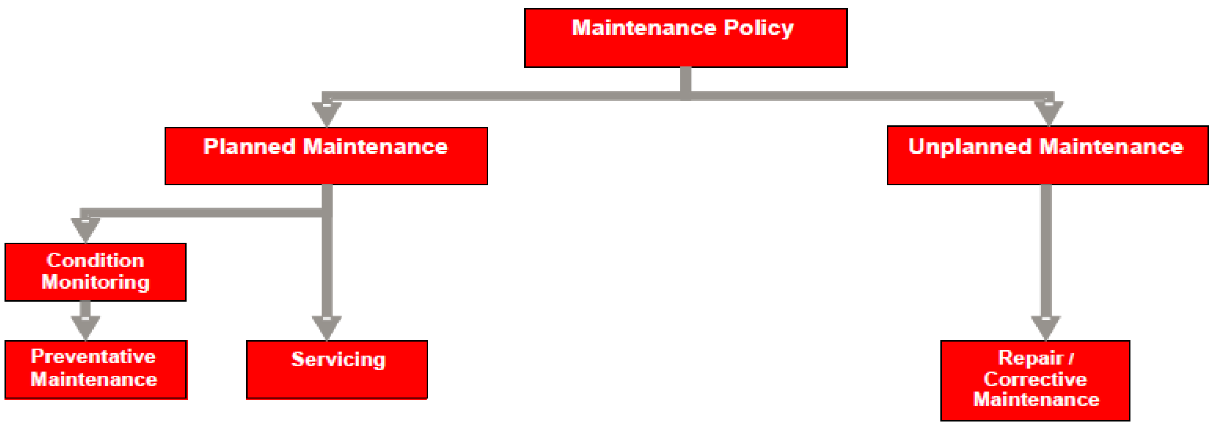


Figure 12: Typical Maintenance Framework (National Treasury, 2008)

National Treasury (2008) provides guidance with respect to determination of EUL of asset is given and typical EULs are tabulated for different asset classes. Deferment of planned maintenance will result in the asset not reaching the envisaged EUL and the guideline proposes that the cumulative effect of deferring maintenance be assessed in order to adjust maintenance budgets that will have a significant impact on the formulation of IAMPs and budgets that are inputs into the municipal IDP.

2.4.2.3. Norms and Standards

Norms and standards were to be developed for different sectors as well as good practice guidelines for maintenance programmes; budgeting norms would be developed based on the maintenance standards to facilitate long-term maintenance budget forecasting that takes into account the type, age and condition of infrastructure (Wall, 2008). The guidelines were to include direction for the following:

- Skills required to plan and manage maintenance programme;
- Different implementation models;
- Maintenance budgeting guidelines such as percentage of infrastructure asset value to be annually set aside;
- Differentiation between types of infrastructure taking into account size, extent, age, level of maintenance, etc.

The Department of provincial and local government (DPLG) formulated a guideline for comprehensive infrastructure plans (CIP) in 2008, which was meant underpin and strengthen IDPs. The DPLG then issued the Guidelines for Infrastructure Asset Management in Local Government in 2010, whose overall application was aimed at assisting in strengthening IDP processes and outcomes, the implementation of GAMAP/GRAP standards applicable to infrastructure assets, improvement of infrastructure investment planning and other local government systems related to municipal infrastructure (DPLG, 2010).

The Guidelines are an interpretation of the International Infrastructure Management Manual for application in South Africa, given the specific legislative, institutional, financial and technical environment, and intend to strengthen baseline competence in the country.

The guidelines propose preparation of long term (10 to 20 years) Infrastructure Asset Management Plans (IAMPs) for all sectors that can be used to inform the shorter term 5 year IDPs (Figure 13).

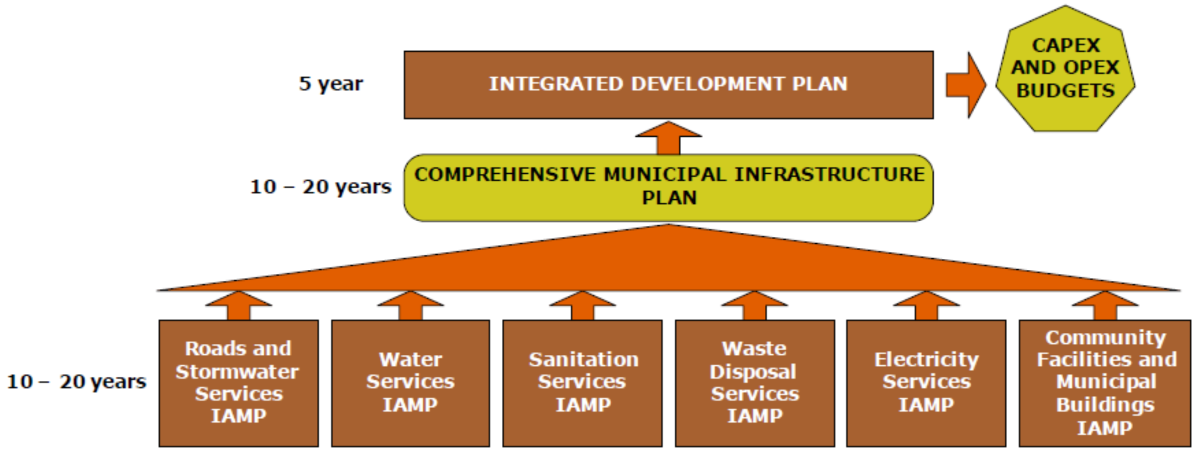


Figure 13: Municipal Infrastructure Plans (DPLG, 2010)

The IAMPs enable municipalities to prioritise projects and determine budgets based on the view of the bigger picture of the entity; asses and put aside optimum funding; and demonstrate the ability to manage and maintain assets (DPLG, 2010). As discussed in section 2.4.1 the IDPs were not supported by sound infrastructure needs, so the Comprehensive Municipal Infrastructure Plans (CMIPs) proposed by these guidelines are a key mechanism to achieve the outcomes of the IDPs. The minimum requirements are indicated in Table 9 for municipalities. The Guidelines also provide typical milestones for improving Asset Management as detailed in Table 10.

Table 9: Responsibilities of municipalities (DPLG, 2010)

Element	**Requirement**
Infrastructure Asset Management Policy	Municipal Council to adopt within 2 years.
Infrastructure Asset Management Strategy	Optional as a separate document.
Integrated Asset Management Plans (IAMP)	To be adopted by Council within 1 year (or IAMP scope covered in sector plan eg WSDP). Update at least every 2 years.
Comprehensive Municipal Infrastructure Plan (CMIP)	First CMIP adopted by Council within 2 years. CMIP to summarize key information and strategic issues across all sectors

Table 10: Asset Management improvement Milestones (DPLG, 2010)

Milestone	Requirements
Stage 1	Improvement Strategy Development
	Needs analysis / status assessment
	Setting base strategy/asset management objectives
	Asset data classification
	Collection priorities confirmed
	Asset management improvement program adopted
Stage 2	Basic Asset Register
	Set up basic asset register
	Asset management information system
	Identification of all assets
	Basic data captured
	Asset replacement cost determined
	Asset replacement timetable determined
	Initial asset management plans
	Current levels of service identified
	Basic valuations prepared
Stage 3	Basic Asset Management
	Improve attribute data
	Introduce basic condition assessment
	Valuation based on condition
	Optimize data collection for critical assets
	Maintenance history data identified
	Second generation (basic) asset management plans prepared
	Renewal decision-making processes documented
	Determine target levels of service based on stakeholder consultation
	Costs captured against assets
Stage 4	Improved Maintenance Management
	Review maintenance procedures
	Apply improved procedures to assets
	Schedule procedure intervals
	Review maintenance plans for key assets
	Begin to introduce asset criticality analysis and risk management
Stage 5	Introduce Advanced Asset Management
	Techniques
	Complete failure analysis on all key asset groups and critical facilities
	Complete consequence of failure (risk management) analysis on all assets
	Apply these findings to the life-cycle strategy and maintenance plans for

	assets
	Valuations based on true economic lives
Stage 6	System Optimisation
	Optimized life-cycle and economic decision making used for planning levels of service, based on ongoing stakeholder consultation
	All options for overcoming failures analysed
	Benefits for each option quantified
	Costs for each option quantified
	Most appropriate strategy for each asset, facility or system identified
	Advanced asset management plans developed

The guideline's proposed useful lives of assets differ from those used in the National Treasury Guidelines on Capital Asset Management; since these documents are both aimed at achieving the outcomes of the NIMS, this can create conflict therefore the EUL must be checked to ensure that it is realistic according to DPLG (2010). The LGCAMG places the responsibilities on municipalities to use their judgement based on operational experience and in consultation with specialists when assessing useful lives.

2.4.3 Sector Guidelines

Sector guidelines were developed to provide details on how to implement the principles contained in the National Treasury and DPLG guides in each specific sector. For non-sector specific assets the LGCAMG should be consulted (National Treasury, 2008). For water services, DWAF announced the *Water Services Infrastructure Asset Management Strategy for Municipal Managers and Management* in 2008 (CIDB, 2008) and it was developed further over a period of two years (DWA, 2011). This is discussed further in section 2.5 that focuses on the water sector asset management landscape and how the developments in the legislative framework discussed in section 2.4 impacts on the management of water distribution networks.

2.4.4 Local Government Turnaround Strategy

The Local Government Turnaround Strategy (LGTAS) was approved in 2009 as an initiative to address the municipal capacity challenges. As part of the LGTAS, the Municipal Infrastructure Support Agent (MISA) was established to co-ordinate the development of Technical capacity in local government. MISA developed a Sector Capacity Development Plan that seeks to develop the institutional capacity of municipalities to enable proper operation and maintenance of municipal infrastructure (MISA, 2013). The *Local Government Regulations on Appointment and Conditions of Employment of Senior Managers* was gazetted in January 2014 in terms of the Municipal Systems Act (Gazette No 37245). The mandate of MISA is informed by these regulations as well as the statutory requirements set by the respective statutory bodies regulating different technical professions (MISA).

In terms of the above Municipal Systems Act amendments, all appointments of Municipal Managers or Section 56 Managers must comply with the competence model to be contained in the regulations (MISA, 2013). Section 56 managers are directly accountable to the Municipal Manager (Municipal Systems Act). Infrastructure/Technical Services Directors as Section 56 senior managers are expected to possess the following requisite qualifications:

- Engineering Council of South Africa (ECSA) accredited qualification;
- Professional registration with ECSA;
- Minimum 5 years' experience, 3-4 of which must have been at professional management level.

Amongst other key outcomes of MISA seeks to attain, the professionalism of technical professions in compliance with statutory provisions will ultimately attain uniform technical skills for various municipal categories, aligning local government regulatory measures for technical functions with international best practices, preventing unqualified personnel from performing technical functions in municipalities, and protection of consumers of municipal infrastructure and technical services (MISA, 2013). MISA also aims to develop general support skills base alongside professional services as illustrated in Figure 14.

For officials without the minimum academic qualification in compliance with statutory provisions regulating technical professions, the MISA Sector Capacity Development Plan aims to roll out a Certificate Programme in Infrastructure Management with universities of technologies (MISA, 2013). Cape Peninsula University of Technology (CPUT) launched a National Certificate in Infrastructure Management aimed at the management of water and wastewater infrastructure; however the accreditation of the programme is still under way (CPUT, 2016).

The University of Capetown (UCT) launched the Postgraduate Masters Level Programme in Civil Infrastructure Management and Maintenance in 2013 aimed at offering training in major disciplines of civil engineering, underpinned by principles of infrastructure management. The Sector Capacity Development Plan is aiming to train 1600 officials by 2019 through these programmes (MISA, 2013).

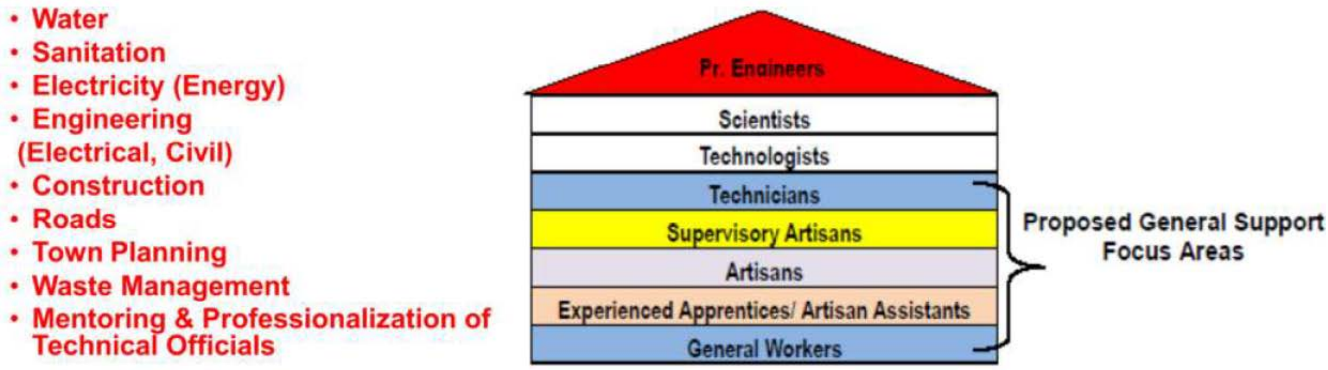


Figure 14: Interventional areas of support per discipline and trade (MISA, 2013)

2.5 Water Services Asset Management Landscape

2.5.1 Water Services Act

The Water Services Act (Act 108 of 1997) requires water services authorities (WSA) to prepare Water Services Development Plans (WSDP). The WSDP is the primary municipal planning instrument with regards to water services (DWA, 2003). Similar to the IDP a 5 year WSDP must be developed and updated on an ongoing basis. The WSDP integrates technical, financial and other water services plans into the IDP process (DWA, 2003). With regards to infrastructure management, the WSDP is required to contain details regarding the operation, maintenance, repair and replacement of existing and future infrastructure.

2.5.2 Infrastructure asset management strategies

The National Water Services Infrastructure Asset Management (IAM) Strategy furthers the aims of the NIMS, GIAMA, LGCAMG and Guidelines for Infrastructure Asset Management in Local Government; and assists water services infrastructure owners with interpretation and alignment of these initiatives (DWA, 2011).

The objectives of the Strategy are to:

- Create coordination platforms for role players to support water services infrastructure management as a national priority.
- Address immediate water services infrastructure failures in water services infrastructure, and effect improvements that can be publicised to demonstrate the benefits of IAM;
- Develop culture of sustained improvement in the management of water services infrastructure.

The summary of the outputs of the strategy with the responsible structures that play a leading role in each are listed in Table 11. For each output the actions were to be detailed in the National Water Services IAM Implementation Plan that was still to be released. Amongst other things the plan would include (DWA, 2011):

- Budget and time frames for implementation;
- A suite of instruments designed to achieve the objectives;
- Prioritisation in terms of both urgency and importance;
- Key performance areas and indicators.

Table 11: National Water Services IAM Strategy Outputs (DWA, 2011)

	Output	Responsibility	Time frame
1	Increased IAM awareness in the water services sector	Stakeholder Reference Group, with DWAF taking the lead	Immediate and over 5 years
2	Greater synergy with water services IAM initiatives achieved	Stakeholder Reference Group and Municipal Reference Group, with DWA taking the lead	Immediate and ongoing
2.1	SYNERGY: IDPs, WSDPs and water board business plans prioritise water services IAM	DWA with CoGTA and National Treasury	Within 1 year
3	Improved WSI IAM through targeted support from national government	Stakeholder Reference Group with DWA, CoGTA and National Treasury taking a leading role	Within 1 year and ongoing
4	Appropriate WSI IAM tools are available and used	Municipal Reference Group and Stakeholder Reference Group, with DWA	Immediate to 3 years
4.1	TOOL: Asset register template	Municipal Reference Group, DWA and National Treasury	Immediate and within 12 months
4.2	TOOL: WSI IAM pro forma recovery plan(s)		
4.3	TOOL: Resources for sound WSI IAM identified		
4.4	TOOL: Water services IAM case studies of lessons and good practice	WIN-SA and WRC with Municipal Reference Group and Stakeholder Reference Group	
5	Water services IAM M&E system developed and linked to current WSI IAM M&E initiatives	Stakeholder Reference Group, with DWA taking the lead	3 to 5 years
6	A regulatory framework is defined and implemented	National Treasury, with CoGTA and DWA	1 to 3 years
7	WSI IAM skills procurement supported through outsourcing	National Treasury and CoGTA, with input from DWA	Immediate and ongoing
8	Appropriate IAM human resources development within WSIs supported	Stakeholder Reference Group in consultation with NIMS and others	Immediate and within 6 months
9	Increased research and development (R&D) and knowledge dissemination in water services IAM	Stakeholder Reference Group and Municipal Reference Group, with WRC taking the lead	5 years
10	Implementation Plan Programme is managed on time, according to budget, and with appropriate guidance	Stakeholder Reference Group and Municipal Reference Group, with DWA providing facilitation, line management and a secretariat, as appropriate	Immediate and ongoing

2.5.3 Blue Drop and No Drop Assessments

Since the inception of the blue drop certification process that was rolled out in 2009, the overall management of water services has been improving as per data presented on Table

12. The blue drop rating indicates the water services institution's compliance with Blue Drop Certification Criteria. A score of 100% means that the Department of Water Affairs (DWA) "has full confidence in the management ability of water services institutions involved in treating, monitoring and managing drinking water in the specific water supply system".

Table 12: National Blue Drop Results 2009-2014 (HST, 2016)

	EC	FS	GP	KZN	LP	MP	NC	NW	WC	ZA
Drinking Water System (Blue Drop) Performance Rating [Definition]										
2009	54.3	40.0	74.4	73.0	40.8	51.0	28.3	40.0	60.3	[1] 51.4
2010	79.4	48.5	85.5	65.9	55.0	65.4	46.9	66.0	92.5	[2] 67.2
2011	77.3	64.1	95.1	80.5	64.0	56.5	62.1	62.3	94.1	[3] 72.9
2012	82.1	73.6	98.1	92.1	79.4	60.9	68.2	78.7	94.2	[4] 87.6
2014	72.0	75.0	92.0	86.0	62.0	69.0	68.0	63.0	89.0	[5] 79.6

EC: Eastern Cape **FS:** Free State **GP:** Gauteng **KZN:** KwaZulu-Natal **LP:** Limpopo **MP:** Mpumalanga **NC:** Northern Cape **NW:** North West **WC:** Western Cape **ZA:** South Africa

The weighting allocated to asset management for instance is 14% in the 2014 blue drop report. Therefore condition of the infrastructure does not influence the Blue Drop score significantly if no maintenance is done and this is not a reliable measure to account for the effectiveness of the total system despite the 2014 report stating that the Blue Drop scores reflect the result for the complete drinking water business for a specific system. Although the overall Blue Drop score may not be an accurate correlation to the state of infrastructure; the 'Asset Management' section of the 2014 National Overview of the Blue Drop report shows that only 68% of systems apply good asset management practices (DWS, 2014c:27) but this may not be obvious in the overall score due to the lower weighting. This indicates that there are challenges present with managing infrastructure for atleast 32% of the other systems and this percentage may be higher since not all systems were covered nationally by the blue drop programme.

In 2013, DWA rolled out the "No Drop" report assessments that are part of efforts to reduce leakages from the water supply networks. The first No Drop assessment was included in the 2014 Blue Drop assessment and accounted for 3% of the overall weighting of the blue drop requirements and national compliance achieved was only 33.72% across the 3 criterion measured for Water Use Efficiency & Water Loss Management (DWS, 2014c). The criterion has subsequently been increased to 7 indicators that include Asset Management and Technical Skills.

2.6 Chapter summary

Maintenance is a critical component of infrastructure management that ensures that infrastructure can reach the end of its useful life in a sustainable manner. Infrastructure maintenance management skills shortage and budgetary constraints threaten the sustainability of water services infrastructure. Since the enactment of the Municipal Systems Acts, and MFMA there has been awareness that maintenance of local infrastructure is paramount in ensuring sustainability of services delivery through effective management of infrastructure. The broad parameters set by these legislative instruments necessitated the development of guiding principles to compel municipal entities to drive maintenance. Initiatives that were implemented as guiding mechanisms such as those associated with the NIMS were very slow in gaining traction and GIAMA has still not been rolled out to local government yet due to various challenges.

The poor maintenance of water distribution pipelines has contributed to high leakage rates in South Africa and to curb water loss municipalities need to adopt policies that embrace total life cycle leakage control strategies as part of maintenance planning. Active leak detection and pressure management strategies are particularly effective in extending the EUL of water distribution pipelines. While ALC approaches focus on mitigating leakage at identified areas, pressure management takes a more holistic long term view and targets one of the root causes of pipe failure and therefore contributes to reduction of service repair frequencies and deferment of pipe replacement.

The present legislative frameworks do not give clear direction with regards to determination of maintenance budgets and budgeting is generally based on operational costs of a municipal entity. Therefore a municipality is expected to establish and organise itself in a manner that will allow it to meet its IDP objectives within its administrative and financial capacity. The international norm for adequate provision of infrastructure maintenance is to base it on current replacement costs of infrastructure. Therefore In order for maintenance budgets to be determined in sustainable manner there has to be proper valuation of infrastructure. Condition assessments are critical in ensuring consistent and realistic valuations of public infrastructure. When GRAP 17 came into effect it became mandatory for annual condition assessments to be carried out but these requirements were later relaxed due to resource and skills limitations for implementation of the requirements.

The Local Government Capital Asset Management Guideline (National Treasury, 2008) provides valuable guidance to municipalities including determination of EUL of assets but these are not consistent with the EUL proposed by the DPLG's Guidelines for Infrastructure Asset Management in Local Government (DPLG, 2010). The actual useful life off water distribution pipelines does not follow a straight line deterioration curve and therefore the EUL cannot be used as a once of planning mechanism for managing water distribution networks. Without the accurate knowledge of the condition of infrastructure, the timing of maintenance or rehabilitation activities is not optimal. Therefore municipalities must align the EUL adopted in their Financial Policies with actual infrastructure performance.

The development of legislative frameworks for management of water services infrastructure has been on-going since 2000. The list of the legislation and policies is summarised in Table 13. The overarching legislative drivers reviewed are the foundation for all sectors and the MFMA in particular is the principal legislation that requires municipalities to responsibly take care of their infrastructure assets and facilitates this through the IDPs. In addition to the IDPs the Water Services Act requires additional planning mechanisms with respect to water services infrastructure the establishment of WSDPs.

Table 13: Water services infrastructure management legislation and guidelines

Publication	Year	Custodian
Acts of Parliament		
Local Government: Municipal Structures Act	1998	Parliament
Municipal Systems Act	2000	Parliament
Municipal Finance Management Act	2003	Parliament
Water Services Act	1997	Parliament
Regulations		
Generally Accepted Municipal Accounting Practice standards	1999	National Treasury
General Recognised Accounting Practice standards	2014	National Treasury
The Local Government Regulations on Appointment and Conditions of Employment of Senior Managers	2014	Department of Cooperative Governance
Strategies		
Water Services Infrastructure Asset Management Strategy for Municipal Managers and Management	2008	Department of Water and Sanitation
National Water Services Infrastructure Asset Management (IAM) Strategy	2011	Department of Water and Sanitation
Guidelines		
Local Government Capital Asset Management Guideline	2008	National Treasury
Guidelines for Infrastructure Asset Management in Local Government	2010	Department of Provincial and Local Government

The flowchart of the reporting structure in local government administration including the key outputs of different leadership levels is presented by Figure 15. The Water services infrastructure maintenance and management framework (Figure 16) is implemented through the operational level, administrative and executive leadership level. The executive leadership of the municipality establish the vision and objectives as well as policies. The administrative level is responsible for implementation of the policies by developing the asset management strategy for local government infrastructure. While, the operational level is responsible for developing the water services infrastructure specific asset management plan and executing tasks associated with the plan.

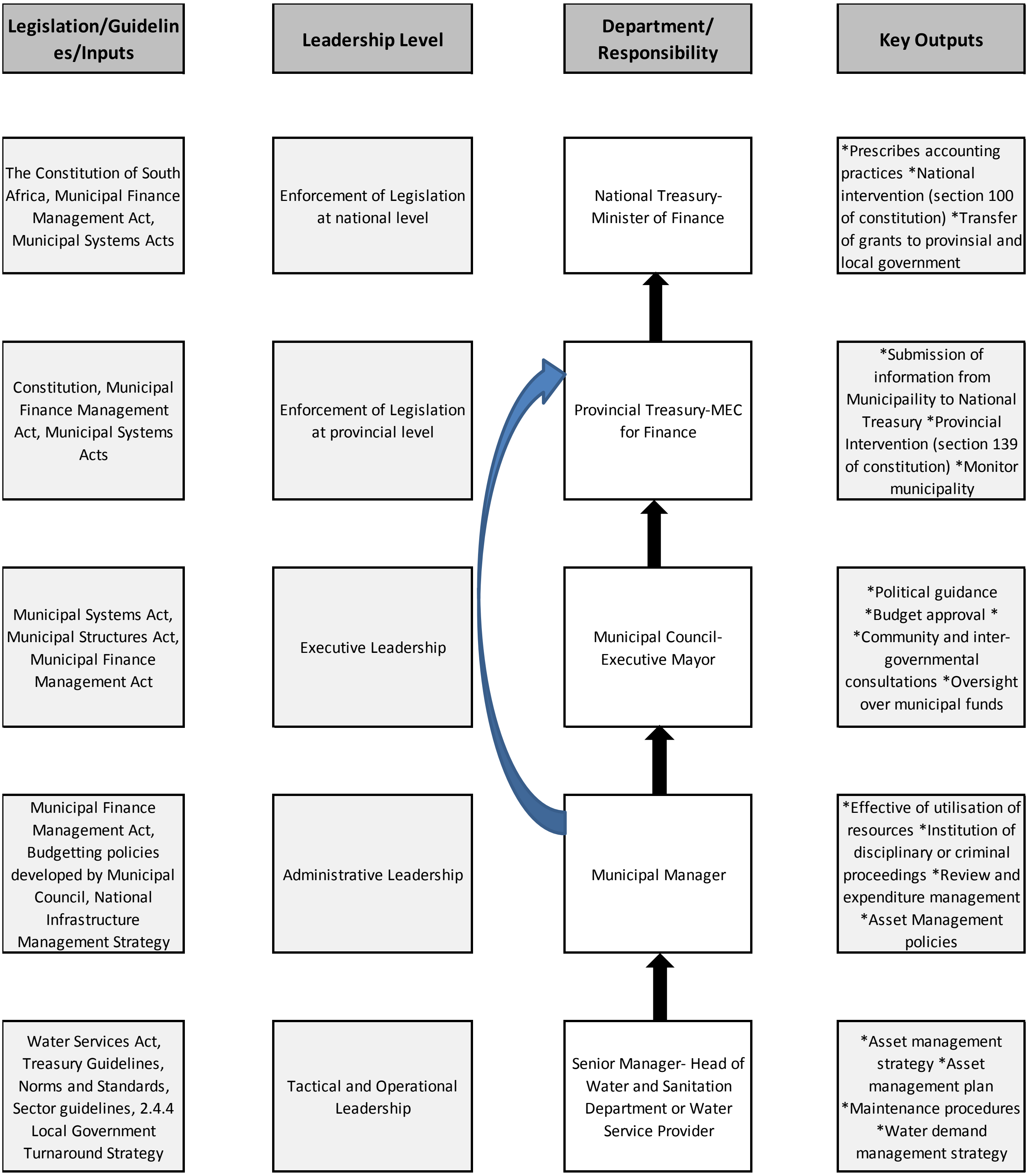


Figure 15: Local government reporting structure, responsibilities and outputs

The *Guidelines for Infrastructure Asset Management in Local Government* (DPLG, 2010) form the basis of the framework presented on Figure 16. The effective implementation of the legislative framework should be able to translate the strategic objectives of municipal entities into workable plans; however the current state of water distribution infrastructure does not reflect the effectiveness of the frameworks. The following chapters aim to investigate the implementation challenges or successes experienced by municipalities in maintenance of local distribution networks.

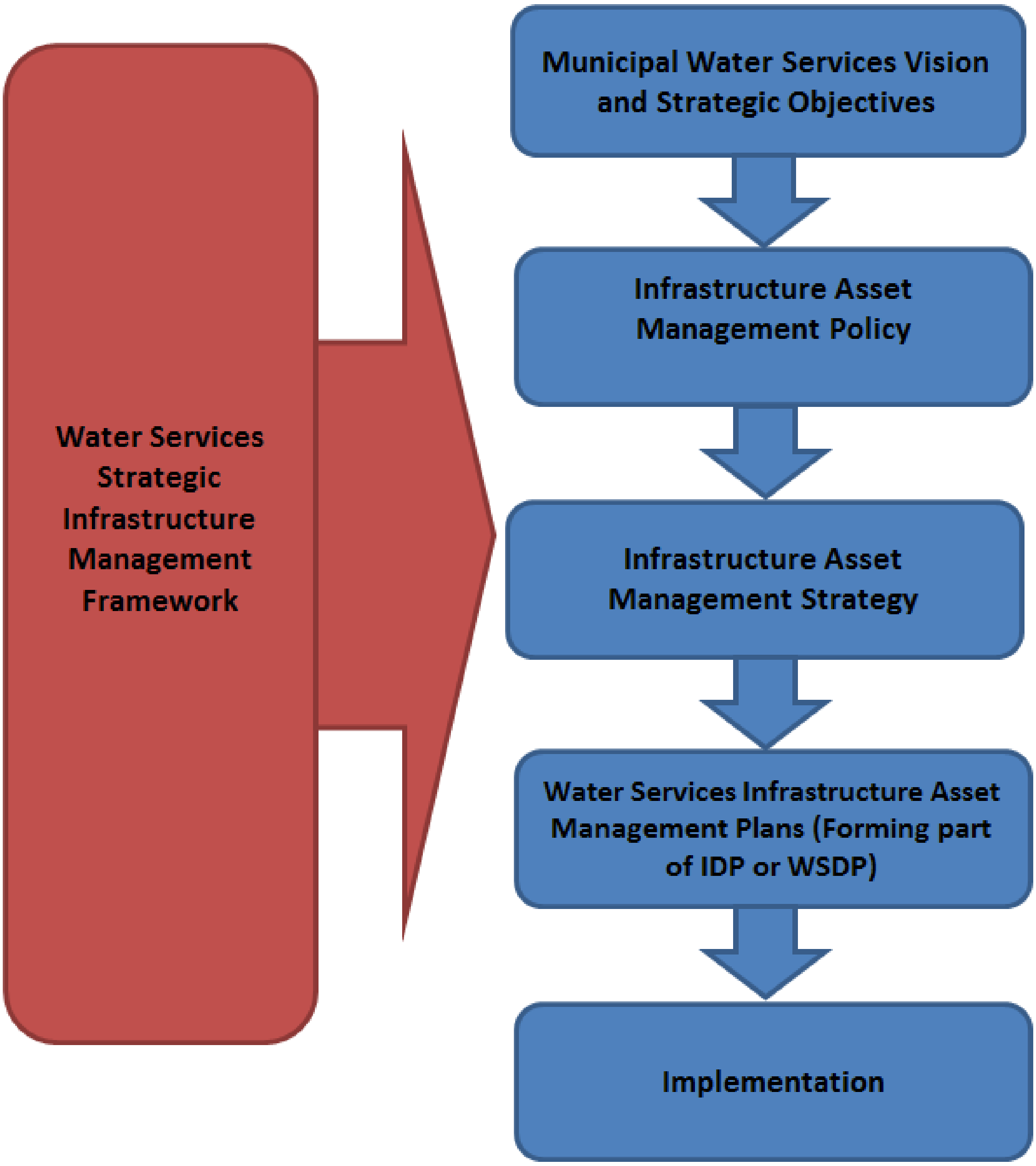


Figure 16: Water Services Infrastructure Management Framework

3. RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the background and rational to the research methodology selected as the best to answer the research question and achieve the research objectives presented in section 1.4. The study seeks to understand how municipalities maintain and manage local water distribution networks and why the level of maintenance carried out is unsatisfactory based on current condition of distribution infrastructure. The author relies on previous studies and reports for available data and no original data were generated for the study.

3.2 Research Design

The study used a qualitative approach to study two municipalities with different social and geographical parameters. According to Augusto & Miguel (2010), qualitative research is an investigation in which the researcher aims to understand a larger reality through its holistic examination or through examination of components of the reality within different contexts. This approach mainly involves collecting data and is based on non-numerical assessment of phenomena using words instead of numerical figures (Nkuna, 2012). The use of methods that are predominantly qualitative are most appropriate for understanding how an outcome has been achieved through a set process, and for evaluating the implementation results of a particular provision of a process or programme (OIR, 2003).

Strategies usually used for qualitative research include action research, case study, ethnography study, phenomenology, and grounded theory (Augusto & Miguel, 2010). A case study approach is best suited when the study aims to answer “how” and “why” questions (Yin, 2003). Case studies are however not only effective in answering “how” and “why” questions; they can also be the basis for developing, testing and refining new ideas and theories (Augusto & Miguel, 2010). According to Augusto & Miguel (2010) case research is the preferred strategy when the researcher has little influence or control over the phenomena to be investigated, and when the focus is on the status quo within a specific real life context.

Case investigation can be categorised as explanatory, exploratory, or descriptive (Baxter & Jack, 2008). This study follows a descriptive case research method. Yin (2003) describes this method as follows:

> ***Descriptive research***: Research in which the case study is used to describe a phenomenon or intervention and the real-life context in which it materialised itself.

This approach sets out to describe and interpret the current challenges, methods adopted in order to describe the status quo and the different factors that contributed to it.

3.3 Data Collection Techniques

The most common data collection techniques in qualitative research are interviews (structured, semi-structured or unstructured), focus groups, observations, and review of documents (Baxter & Jack, 2008). The main data collection technique used for this study was documentary analysis. Although document analysis has mostly been adopted to compliment other research methods, Bowden (2009), highlights that it can also be used as a stand-alone case research method. The author has identified documents as the only necessary data source due to the study having an interpretive paradigm with respect to the status quo as suggested by Bowden (2009).

3.4 Data sources

All the data used for the study was obtained from secondary sources. The major sources of data were from local and national government publications, municipal annual reports and public presentations, voluntary organisations, previous studies and journal articles.

3.5 Document Analysis Instruments

Document analysis is a type of research method that requires data to be selected, examined and interpreted to gain understanding and develop empirical knowledge; this is achieved through skimming through documents, rough examination and eventually interpretation of the data (Bowden, 2009). According to Labuschagne (2003), document analysis extracts data, quotations, and passages that the researcher needs to organise into major themes, categories, and previous case examples.

There are different instruments that can be used to compare and contrast existing documentation and studies. Document analysis is carried out through quantitative content analysis or through the qualitative approach to content analysis (Boomsma, 2013). According to Bowden (2009), "content analysis is the process of organising information into categories related to research questions". Therefore, the author identified meaningful and relevant passages of text or other data and separated it from information that is not pertinent to the research questions.

The document analysis focused on the water services infrastructure management framework introduced in the concluding section of Chapter 2 (Figure 16). For the identified study areas Table 14 depicts the key questions used to extract data from the documentary analysis based on the framework. The final layer of the framework (Implementation) focuses specifically on maintenance aimed at reducing leakage in the distribution networks. For each study area an assessment matrix adapted from (Makaya & Hensel, 2012) was developed to assess leakage control strategies; the following assessment parameters were used for strategies currently implemented:

a) Strengths (enabling factors that support the implemented strategy)
b) Challenges (shortfalls of strategies and barriers to implementation)
c) Threats (lack of skills, resource constraints and insufficient funding)
d) Opportunities (Improvement of interventions based on recommended best practices)

These parameters were assessed based on the model developed by Wegelin (2015) for assessing physical loss reduction interventions (Table 15) as well as leakage control best practices discussed in the literature survey.

Table 14: Maintenance Framework Validation Questions

Infrastructure development Vision and Objectives (IDP)	• What's the Municipality's vision, mission and strategic objectives as per IDP • Are challenges in the water distribution highlighted at the strategic level? • Does the entity have WSDPs as required by Water services Act and are they aligned to IDPs?
Infrastructure Management Policy	• Does the municipality have an infrastructure asset management policy? • Does the policy include over-arching principles and overall organisational commitment to improvement of infrastructure?
Infrastructure Management Strategy	• Does it define key infrastructure management processes and standardized procedures? • Does it allocate responsibility for infrastructure asset management to specific individuals? • Does it define the process to be adopted in managing physical risk of networks? • Does it require the preparation of a comprehensive municipal infrastructure plan each year to inform the IDP?
Water Services Long term Infrastructure Asset Management Plans (Forming part of IDP or WSDP)	• Does the entity's Comprehensive Municipal Infrastructure Plans or Comprehensive Asset Management Plans include Water Services established in terms of Municipal Services Act? • Does the asset management plan document the nature, extent, age, utilisation, condition, performance and value of the water distribution infrastructure? • Do the plans include a risk management process? • Do the plans assess the infrastructure asset management practice and identify improvements?
Maintenance Implementation	• Are maintenance plans aligned with asset management plans? • Are maintenance budgets prepared in accordance to the policies and is funding adequate? • Are condition assessments carried out in accordance with GRAP 17 requirements? • Is pressure management used for reducing leakage? • Are pipelines rehabilitated at the end of their useful life? • Are resources available and required skills available?

Table 15: Analysis of physical water loss interventions (Wegelin, 2015)

- **Pressure management**
  - System pressure below allowable maximum
    - Monitor and control sector and DMA pressures
    - Monitor burst frequencies and identify problem areas and pipelines
    - Review maximum pressure policy and reduce if possible
  - System pressure above allowable maximum
    - Perform pressure analysis using PRESMAC
    - Reduce pressures through sectorisation or PRVs
    - Implement advanced pressure management control
- **Leakage control**
  - ALC programme
    - Night flow analysis
      Perform regular or continuous flow logging sectors and DMAs
      Monitor and control night flows and analyse using SANFLOW
    - ALC programme
      Develop an ALC programme
    - Passive leakage control programme
      Continuously promote reporting of leaks through customer care centre
      Monitor and assess number of calls per month.
      Ensure all reported leaks are fixed within 48 hours.
  - No leakage control programme
    - Analyse MNF, burst frequencies and pressures to prioritise sectors and DMAs
    - Setup and train an active leak detection team
    - Promote reporting of visible leaks by the community
- **Mains replacement**
  - Low burst frequency
    - Implement main replacement programme
  - High burst frequency
    - Gather mains replacement management information
    - Analyse management information and determine priority areas and pipelines
- **Speed and quality of repairs**
  - All leaks are repaired in less than 48 hours
    - Sustain speed and quality of repairs to remain below 48 hours
  - Leak are repaired in excess of 48 hours
    - Identify factors that influence the speed and quality of repairs
    - Implement corrective measures
    - Monitor and control speed and quality of repairs

Legend: ? Question ✓ Yes ✗ No

3.6 Study areas

The 8 metropolitan municipalities in South Africa are home to about 40% of the whole population of the country. Therefore the study areas chosen are two metropolitan municipalities and were chosen as the main focus of the research due to the overall demand of the 8 metros that accounts for 46% of total urban water use (DWA, 2013). The two metros are:

1) City of Capetown (Western Cape Province)

2) City of Johannesburg (Gauteng)

The City of Cape Town Metropolitan municipality was chosen on the basis of having the lowest ILI (Table 2) to serve as a benchmark while the city of Johannesburg was chosen on the basis of a high ILI accompanied by the highest leakage rates on mains and connections. These Metropolitan municipalities are characterised by multiple industrial areas and business districts, high population densities, and a dynamic movement of people, goods and services (Jantjes, 2007).

3.6.1 City of Cape Town

3.6.1.1. Background

The total area of the City of Cape Town is 2461 km^2 with an estimated population size of 3.74 Million (1530 persons/km^2) and just over 1 million households (Stats SA, 2017). According to Stats SA (2017) 75% of household have piped water inside their dwellings. The City of Cape Town currently boasts the lowest level water leakage for any Metropolitan municipality in the South Africa. The city's network services 8 districts as indicated on Figure 17.

The local water distribution network consists of approximately 10400 km of pipelines distributing about 880000 m^3 of potable water per day (CCT, 2016a). The pipelines consist of different types of materials including Asbestos Cement (AC), Cast Iron, Steel, PVC, uPVC, GRP, Pre-stressed concrete or steel, and other unknown materials (Abdelgadir, 2012). AC pipelines account for about 73% of the network (Table 16).

Figure 17: City of Cape Town water distribution districts

Table 16: City of Cape Town Water Distribution Mains Material (Abdelgadir, 2012)

Material	Percentage of Network (%)
Asbestos Cement (AC)	72.9
Unplasticised Polyvinyl Chloride (uPVC)	5.48
Unknown	5.41
Steel	5.3
Cast Iron Concrete Lined	4.86
Cast Iron	2.91
Steel Concrete Lined	1.57
Concrete	0.59
High Density Polyethylene (HDPE)	0.41
Polyvinyl Chloride (PVC)	0.3
Glass Fiber Reinforced Plastic (GRP)	0.11
Steel Bitumen Lined	0.06
Cast Iron Bitumen Lined	0.06
Prestressed Concrete	0.03

The age distribution of the water mains based on 10 year intervals has a wide spread spanning over 60 years (Table 17). The length of the pipelines below 20 years of age represents more than 40% of the overall network and indicates that there were significant investments that were made in new pipelines since 1994. However, more than 20% of the network is over the 50 year recommended pipeline replacement cycle that was discussed in section 2.3.5.3. Cape Town is South Africa's oldest city and the owner of some of the oldest infrastructure which includes water distribution pipelines; the average age in 2012 was 33 years (Rodkin, 2012).

The city's Water and Sanitation department responds to about 3200 pipe bursts a year and 30000 connection leaks (CCT, 2016b). According to Abdelgadir (2012) the City of Cape Town has been maintaining data for the failures of water mains since 1980 and the dataset in the city's records includes information about the mains such as the location of the failing pipe in terms of the suburb and the street name, the material of the pipe, the diameter, and the failure date. (Abdelgadir, 2012) highlights that the failure data did not reflect the age of the pipes. According to Rodkin (2012) Age is not necessarily a criterion for replacement of the City's network as performance takes priority over age.

Table 17: Length of pipelines for different age categories (Abdelgadir, 2012)

Age (years)	Length* (m)
0-10	1406276
11-20	3074186
21-30	1419872
31-40	1049672
41-50	1148060
51-60	266974
> 60	1824960

* Length based on 2011 figures

3.6.1.2. Organisational structure

The Water and Sanitation department falls under the Utility Services directorate, which reports to the City Manager (Figure 18). The Executive Director of Utility Services and the Director of the Water and Sanitation department are professional Civil Engineers registered with the Engineering Council of South Africa (ECSA) (ECSA, 2017). In 2012 the Utility Services directorate had approximately 8000 employees including 200 engineers, technologists and technicians (Lepheana, 2012). However, the city's WSDPs and Annual reports reviewed as part of this study do not provide a breakdown of how many employees are employed in the Water and Sanitation department specifically as well as the status of professional registration with ECSA.

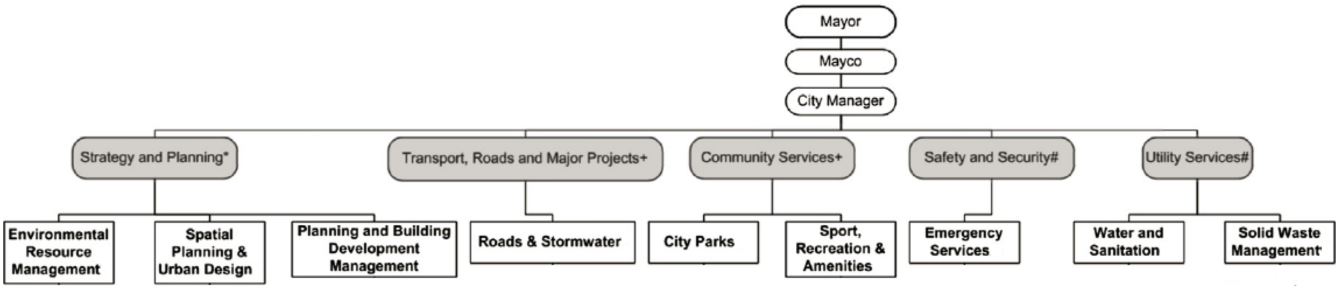


Figure 18: City of Cape Town's organogram up to the second reporting level (Celliers et al 2014)

The City of Cape Town established a dedicated water demand management section within the Water and Sanitation Department to implement the city's Water Demand Management Strategy (Basholo, 2016). The department is also responsible for the water reticulation, engineering and asset management with respect to water services infrastructure (Celliers *et al* 2014).

3.6.2 City of Johannesburg

3.6.2.1. Background

The City of Johannesburg's water services are delivered by Johannesburg Water (JW), which is a Water Services Provider (WSP) wholly owned by the city. JW operates as a private company however remains subject to the Municipal Finance Act (Marin *et al,* 2009) and also governed by the Water Services Act (JW, 2017a). It serves an estimated population of 4.4 Million people over an area of 1645 km^2 (2696 persons/km^2) and just over 1.4 million households (Stats SA, 2017). 65% of the households have piped water inside their dwellings. The City of Johannesburg is divided into the following seven regions as indicated on Figure 19.

JW supplies potable water through a network made up of 12581 km of water pipelines, distributing almost 1.6 Million m^3 per day (JW, 2015a). In 1988 the total length of mains in the city of Johannesburg was only 3100km (Fox & Verrier, 1991); therefore approximately 75% of the current network is under 30 years old. Based on JW (2013b) data, in 2013 64% of the network had a remaining life of more than 20 years and 24% of the network requires replacement within 10 years staring from 2013 (Table 18). According to JW (2015b) the water distribution network has consumed 45% of its useful life as of the end of 2016.

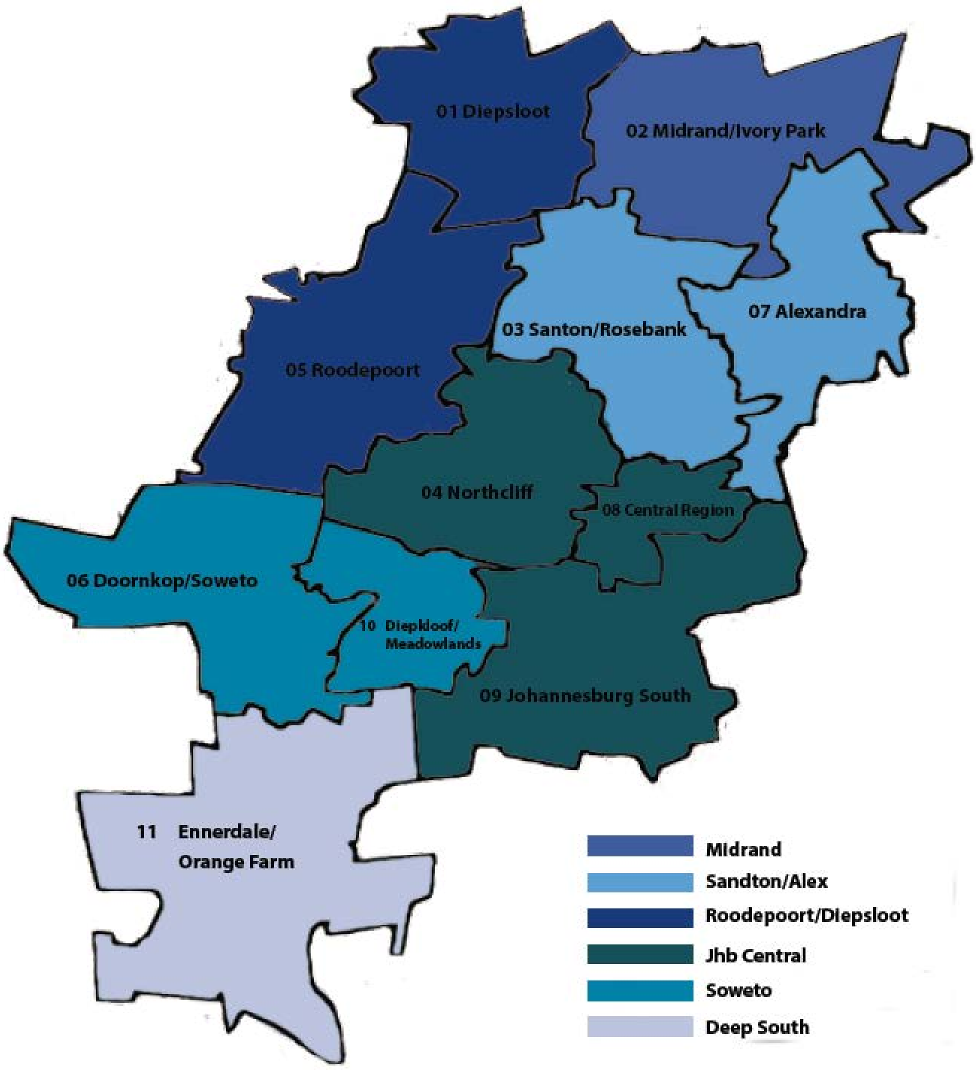


Figure 19: Johannesburg Water regions (JW, 2016)

Table 18: COJ's remaining useful life of water distribution network (JW, 2013b)

Ranges (years)	**0-5**	**6-10**	**11-20**	**>20**
Length of mains (km)*	2139	881	1510	8052
% of network*	17	7	12	64

*based on 2013 data

Before the early 90s the City of Johannesburg followed a reactive approach to maintenance of the water distribution network and this resulted in very little planned and routine maintenance of the system that led to deterioration of the network and major component failure under operating conditions (Fox & Verrier, 1991). The city then started to embark on a programme to improve the condition of the network in 1988 (Figure 20). Burst records and leakage control systems alongside a planned maintenance programme were key criteria for replacement and refurbishment of water distribution pipelines.

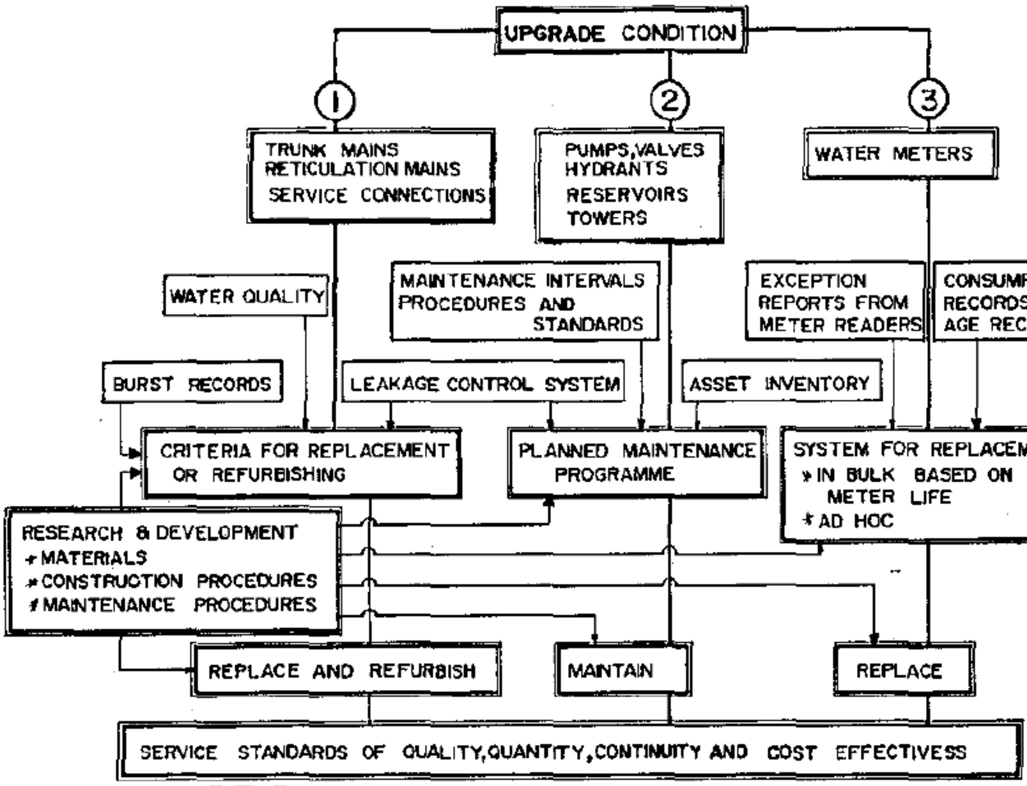


Figure 20: Condition improvement programme (Fox and Verrier, 1991)

3.6.2.2. Organisational Structure

JW is managed by the Managing Director (MD) and is supported by different teams indicated on the organisational structure presented on Figure 21 (JW, 2017c). The MD is accountable to the Board of Directors of JW and the Board of Directors is accountable to the City Manager as illustrated by the Organisational Structure of the City of Johannesburg (Figure 22) (JW, 2017c; COJ, 2017; COJ, 2015).

The Chief Operations Officer (COO) of JW is responsible for water services infrastructure planning, asset management, infrastructure investments, and asset performance monitoring and Evaluation (JW, 2013b). The ECSA database of registered persons indicates that the current MD and COO are registered as Professional Civil Engineers with the ECSA (ECSA, 2017).

The engineering capacity of Johannesburg Water for the 2015/16 FY consisted of a total of 25 professionally registered engineers, technologists and technicians out of a pool of approximately 821 experienced specialists, middle management, junior management and academically qualified employees (JW, 2015b; JW, 2013b). The total staff complement including technical support services (semi-skilled and unskilled labour) is approximately 2500 (JW, 2013b). Johannesburg Water also has a programme in place to promote the development of engineers to register with ECSA as professionals (JW, 2013b).

Figure 21: Johannesburg Water organisational structure (JW, 2013b)

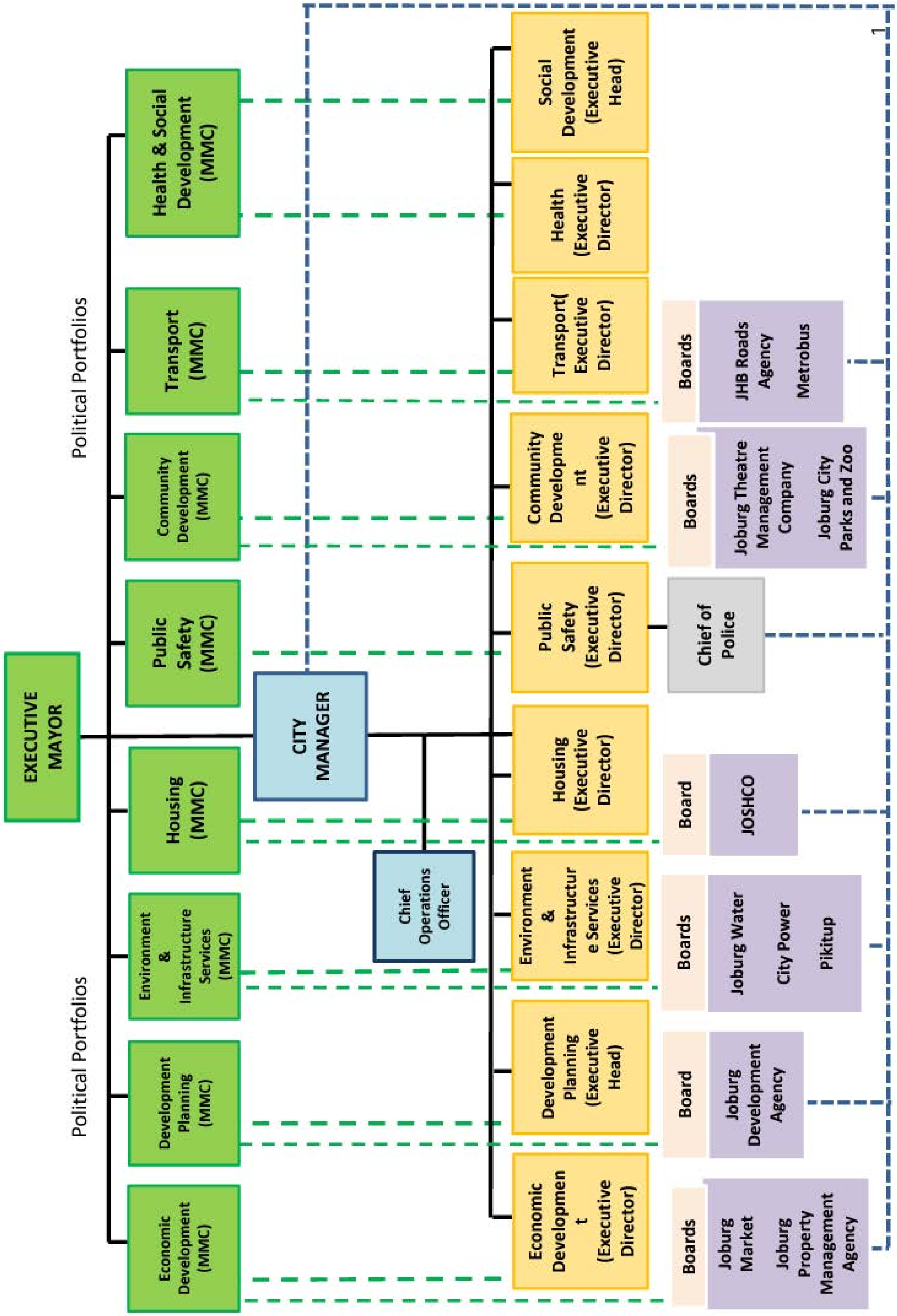


Figure 22: City of Johannesburg organisational structure (COJ, 2017)

3.7 Chapter summary

The City of Johannesburg is the largest metropolitan municipality, followed by the City of Cape Town. The water distribution networks managed by these two Metropolitan cities serve a population of almost 9 million people; which translates to 40% of all Metropolitan municipalities or 17% of the country's population.

Case study research methodology was chosen for this study and looked at the strategic objectives, maintenance policies and asset management strategies for the purpose of comparing, describing, contrasting, classifying, analysing and interpreting the study areas and the factors most pertinent to the research question.

The data for analysis was collected through documentary analysis of publicly available records and reports. Data collected was limited to water distribution infrastructure that includes pipeline, pressure management devices, leakage detection and repairs. The data was assessed based on the water services infrastructure management and maintenance frameworks to identify gaps and best practises that have been adopted by the study areas. The findings and discussion of results are presented in the following chapter.

4. RESEARCH FINDINGS AND DISCUSSIONS

4.1 City of Capetown

4.1.1 Water Services Integrated Development Plans

4.1.1.1. Integrated Development Plan

The first Integrated Development Plan (IDP) for the City of Cape Town was released in 2003 for the 2002-2007 five-year period in response to the Municipal Systems Act's implementation which had just been rolled out earlier in 2000; the Municipal Systems Act is the main piece of legislation regulating the development of the IDP.

The vision and mission of the City of Cape Town contained in the current five year IDP (2012-2017) is threefold (CCT, 2013b):

- "To be an opportunity city that creates an enabling environment for economic growth and job creation"
- "To deliver quality services to all residents"
- "To serve the citizens as a well-governed and corruption-free administration"

This vision has been translated into eight strategic focus areas for the current IDP; these effectively form the framework of the five-year IDP (CCT, 2013b):

1) Shared economic growth and development
2) Sustainable urban infrastructure and services
3) Energy efficiency for a sustainable future
4) Public transport systems
5) Integrated human settlements
6) Safety and security
7) Health, social and community development
8) Good governance and regulatory reform.

Focus area 2 (***Sustainable urban infrastructure and services***) was targeted at infrastructure used in the delivery of sustainable basic services. Challenges that the city was faced with were highlighted and these included budget and resource constraints that made it impossible for all infrastructure requirements to be met simultaneously (CCT, 2007a). Focus area 2 was divided into several areas that included the conservation of natural resources. One of the core objectives identified was the development of "demand management programmes for water, electricity, waste and transport and reduce pollutants". Water demand management was therefore one of the issues captured at a strategic level.

4.1.1.2. Water Services Development Plan

The sector plan of the city's IDP for water services is the Water Services Development Plan (WSDP); its development process is fully integrated into the IDP process (CCT, 2009). The WSDP aligns capital expenditure with operational and maintenance requirements (CCT, 2015b). The City of Cape Town prepares and maintains a Water Services Development Plan (WSDP) every five years and reviews the plan annually in line with the IDP review timelines.

For the 2012-2017 IDP term, the matrix on Table 19 illustrates how the IDP strategic focus areas are accommodated within the strategic thrusts of the WSDP. For maintenance and new infrastructure investments the Water Services Infrastructure Profile business element of the WSDP supports the IDP. The WSDP infrastructure profile indicates the current replacement cost and extent of the water distribution network. The WSDP stipulates a maintenance allowance of 1% of the replacement cost of the infrastructure.

The City of Cape Town's previous WSDPs identified that maintenance of infrastructure was mostly reactive due to the lack of an asset management strategy (CCT, 2007a; CCT, 2009). The 2007 WSDP highlighted the importance of minimising long term ownership costs of water and sewer reticulation networks which account for a large proportion of the total replacement cost of the City's infrastructure. One of the goals of the WSDP was to establish efficient and effective Water Services Institutional Arrangements and this includes the establishment of an efficient and effective asset management program for the Water and

Sanitation Department (CCT, 2009). The WSDP recommended improvement of condition records including the maintaining a thorough record of mains burst records to be able to develop a comprehensive pipe replacement programme.

Table 19: Extract of IDP Priority Issues Relating To Water Services (CCT, 2015a)

Strategic Focus Area (SFA)	IDP Objective	IDP Programme	Water Services Business Elements									
			1. Socio - Economic Profile	2. Service Level Profile	3. Water Resource Profile	4. Water Conservation / Demand Management	5. Water Services Infrastructure Profile	6. Water balance	7. Water Services institutional arrangements Profile	8. Customer Service Profile	9. Financial profile	10. List of Projects
1.THE OPPORTUNITY CITY	Objective 1.1 - Create an enabling environment to attract investment to generate economic growth and job creation	No Direct Programme – Linked to Objective 1.2	x									
	Objective1.2 - Provide and maintain economic and social infrastructure to ensure infrastructure-led economic growth and development	P1.2(b) Maintenance of infrastructure					x					
		P1.2(c) Investing in Infrastructure					x					
		P1.2(d) Expanded Public Works Programme (EPWP)	x	x								
	Objective 1.3 – Promote a sustainable environment through efficient utilization of resources	1.3(b) Water Conservation and Water Demand Management Strategy			x	x	x	x			x	x

The WSDP incorporates the Water Demand Management Strategy that was developed as one of the outcomes of the Western Cape Water Supply System (WCWSS) Reconciliation Strategy; this is a strategic planning study that was conducted to ensure that future water supply and demand could be reconciled (CCT, 2007a). The City of Cape Town approved a 10 year water demand management strategy in 2007 (Basholo, 2016) and this is considered is a core requirement for sustainability of water supply to the City of Cape Town (CCT, 2009).

4.1.2 Asset Management Framework

4.1.2.1. Asset Management Policy

The City of Cape Town has an overarching Asset Management Policy for infrastructure assets. The objective of the policy is to establish a framework for safeguarding of assets (CCT, 2013c). The policy stipulates the following:

1) The responsibilities of the city manager and various departments within the City regarding assets.
2) The processes and guidelines for recognition and classification of assets.
3) Means of safeguarding assets.

4) Changes that require data updates on asset register.
5) Procedures and governance for disposal or retirement of assets
6) Annual asset verification process
7) Maintenance strategy formulation and maintenance management responsibilities.

All the departments in the City of Cape Town's administration are required ensure that all their employees adhere to the approved asset management policy that informs asset management plans for different sectors/departments within the city (CCT, 2013c).

4.1.2.2. Comprehensive Asset Management Plan

In the period 2007-2008 a comprehensive asset management plan (CAMP) was developed in line with the Five-Year 2007-2012 IDP. The purpose of the asset management plan was to standardise the City's asset maintenance and new infrastructure delivery programmes (Neilson, 2008). The Integrated Asset Management Plan was developed on a co-ordinated basis across all directorates in the City (CCT, 2015a). Its objectives were as follows (Neilson, 2008; CCT, 2010a):

- Provide comprehensive detail of the City's current infrastructure.
- Provide comprehensive detail regarding the maintenance status of the existing City infrastructure.
- Provide an upgrade and maintenance programme for the City's existing infrastructure.
- Provide funding requirements (and cash flows) for the maintenance programme.
- Project the infrastructure requirements for new City developments.
- Ensuring that a GRAP-compliant asset register is developed and maintained;

The City of Cape Town adopted the Asset Management Improvement Framework (Table 10) recommended in the Guidelines for Infrastructure Asset Management in Local Government (CCT, 2010b). The City's Water and Sanitation department then subsequently grew its "asset management maturity" by implementing AMIP (CCT, 2009). The AMIP was managed through the City's Reliability Engineering team (Formerly known as the Asset Care Centre). Reliability Engineering is the central hub where all maintenance and asset related information is recorded (CCT, 2010b). The centre was established in March 2004 and managed by PRAGMA until September 2006; during this period there was a skills transfer process to train the city's staff to take over the Reliability Engineering Function (Mosai, 2006). Reliability Engineering is currently being managed by the Water and Sanitation department and the city of Cape Town also bought the AMIP from PRAGMA (CCT, 2010b).

The aim of the AMIP is to ensure the following (CCT, 2009):

- "Assets are maintained proactively".
- "The total asset lifecycle is managed to maximise life of asset".
- "Maintenance work is effectively coordinated".
- "Operational downtime is significantly reduced".

By 2010 the Water and Sanitation department had achieved Stage 3 (Basic Asset Management) as per improvement requirements listed in Table 10, but there were still gaps in the equipment register and maintenance plans (CCT, 2009).

4.1.3 Water Demand Management Maintenance and Rehabilitation Strategies

For reticulation water mains the City of Cape Town aimed to achieve a burst rate of less than 10 bursts/100km/ year in the 2012/17 period (CCT, 2015a). One of the strategic goals of the Water Demand Management Strategy is to reduce water losses to below 15% (Basholo, 2016). Since the development of the Water Demand Management strategy in 2001 a number of interventions were implemented by the city of Cape Town. The city of Cape Town adopted the following leakage control strategies:

1) Active leakage control
2) Pressure management
3) Mains replacement
4) Response time and quality of repairs

Some of the outcomes of the strategies were very successful and received wide recognition (CCT, 2007a). Pressure management is a key component of the water demand management interventions that have been implemented (Mckenzie, 2014). Table 20 depicts the real loss reduction approaches preferred by the City of Cape Town; pressure management is the most preferred strategy with the highest benefit achieved at the lowest cost and schedule. Mains replacement is considered the last resort in terms of implementation order and its high cost and complexity to execute timeously.

Table 20: City of Cape Preferred Real Loss Reduction Criteria (Basholo, 2016)

Leakage control strategy	Preferred Implementation order	Relative benefit ranking	Relative cost ranking	Implementation time ranking
Pressure Management	1	1	1	1
Active Leakage Control	2	3	2	2
Speed and Quality of repairs	3	4	3	3
Mains rehabilitation and replacement	4	2	4	4

4.1.3.1. Pressure Management

To date the City of Cape Town implemented some of the following pressure management projects:

- The first major pressure management programme rolled out was in Khayelitsha in 2001 and it achieved a saving of 9 million m^3 per annum (1 million litres of water an hour (McKenzie & Wegelin, 2010). The water savings achieved allowed new supply infrastructure investment to be postponed by atleast two years.
- The city of Cape Town's second largest pressure management installation was commissioned in Mitchells Plain in November 2008 (Meyer *et al*, 2009). Savings of 2.4 million m^3 per annum were achieved in 2009 (McKenzie & Wegelin, 2010).
- Pressure Management was successfully installed in Melkbos, Brakloof, Dennehoek, Mountainside, Lynns View and Pelikan Park from 2013 to 2014 and estimated savings achieved were around 2.23 million m^3 per annum (0.25 Million litres per hour) (CCT, 2015a).
- Pressure Management was successfully installed in Sunningdale, Imhoff's Gift, Wynberg 3 Zone B, Vrygrond, Masiphumelele, Therina, Helderzicht and Silverboom.

Savings achieved from this intervention are estimated to be around 8.24 million m^3 per annum for the 2015/2016 year (CCT, 2017).

By 2010 pressure management had been extended to a number of other areas in the city including Gugulethu, Atlantis, Mfuleni, Delft, Belhar, Langa and Eesterivier (Meyer *et al*, 2009). The associated annual cost savings associated with pressure management are summarised in Table 21. The pay-back period for the intervention is typically found to be less than a year for the installations.

Table 21: Pressure Management Water and Cost Savings (Meyer et al, 2009)

Area	Water Savings (million m3/year)	Implementation Cost (R)	Cost Savings @R6.20/ m3 (R/ year)
Khayelitsha	9 million m^3/yr	2.7 mill (2001)	R 55 million/yr
Mfuleni	0.4 million m^3/yr	1.5 mill (2007)	R 2.5 million/yr
Gugulethu	1.6 million m^3/yr	1.5 mill (2008)	R 10 million/yr
Mitchells Plain	2.4 million m^3/yr	7.7 mill (2009)	R 15 million/yr

To ensure continued effectiveness of Pressure Management interventions the city is planning to roll out Advanced Pressure Management projects in the next five years. These programmes will entail installing real time monitoring systems of pressure management devices (CCT, 2017). Although the city has identified many areas to be pressure managed, there are areas where it cannot be used, particularly areas with steep gradients (Meyer *et al*, 2009). The maintenance of Pressure Relief Valves has been identified as one of the critical interventions to sustain achieved water loss reductions (Figure 23).

4.1.3.2. Active Leak Detection and Repairs

The City of Cape Town identified a list of priority areas to be targeted for active leak detection and repair. This list is based on areas in which pressure management has been implemented but the minimum night flows are still higher than expectations (CCT, 2015a).

According to Basholo (2016) the Water and Sanitation's department has three active leak detection and repair teams:

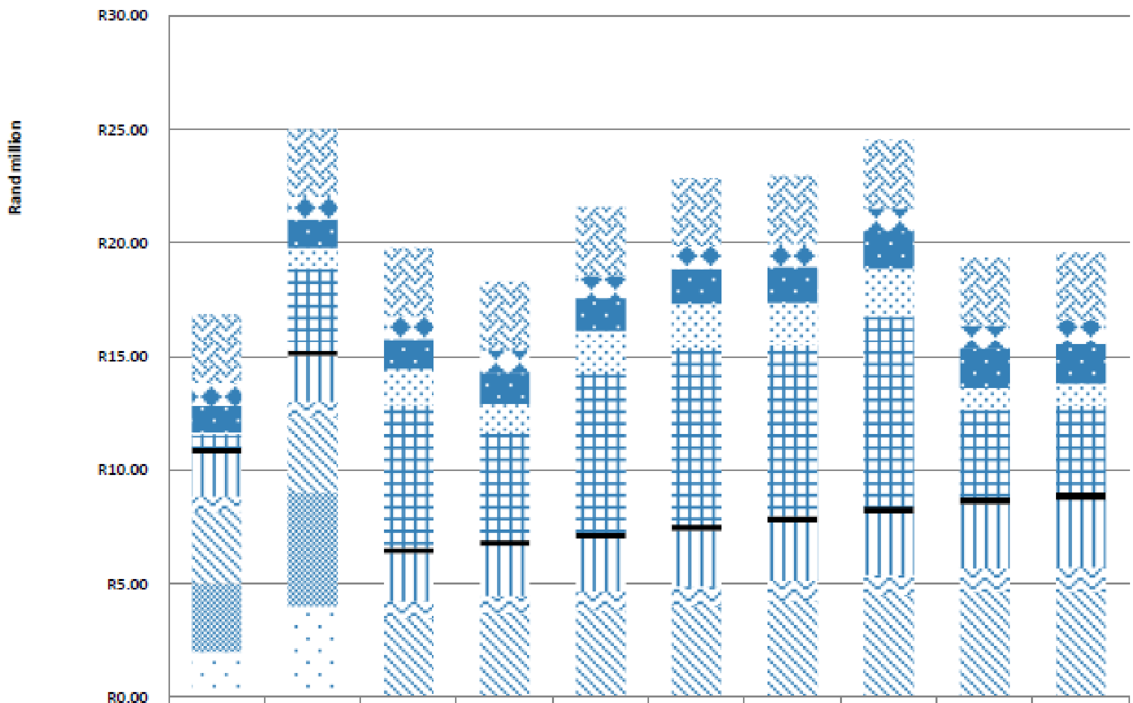
- Field Measurements Team
- Basic Leak Detection (visual surveys) Team
- Non-visible leak detection Team

The teams were setup in adherence to the goals of the 2009 WSDP. The leak detection team started with leak detection in July 2013 and successfully completed the leak detection and repairs in Kuilsriver (CCT, 2015a). The city of Cape Town surveyed almost 150 km of distribution mains in the between 2013 and 2015 in the areas listed on Table 23 (Basholo, 2016). An earlier forecast done in 2006 estimated that the establishment of leak detection task teams would result in potential savings of 2 million m^3 of water per annum (Table 22). However, implementation funds for leak detection projects were only approved from 2013 (CCT, 2015b). Although there was progress made in repairing detected leaks in some sub-zones (Table 23), Basholo (2016a) noted that leaks were generally not repaired timeously; by 2016 leaks detected between 2014 and 2015 in Mfuleni, Du noon and Pella were still in the planning phase.

Table 22: Cost forecast - Pressure Management and Leakage Control Water Savings (CCT, 2007b)

	Pressure reduction		Establishment of leak detection task teams	
Year	**Cost (R million)**	**Savings (Mm^3/a)**	**Cost (R million)**	**Savings (Mm^3/a)**
06/07	3	2.4	1.4	0.4
07/08	2.9	2.3	1.0	0.3
08/09	2.9	2.3	1.0	0.3
09/10	0.05	0	1.0	0.3
10/11	0.05	0	1.0	0.3
11/12	0.05	0	1.0	0.3
12/13	0.05	0	1.0	0.3
Total	**9**	**7.1**	**7.4**	**2.0**

The active leakage control strategy has faced financial constraints since the implementation of the water demand management strategy. However, from 2013 this situation has improved and it can be seen from Figure 23 that significant investment has been planned from 2014 until 2024 to sustain water loss savings and to locate areas where improvements can be made (CCT, 2015b).



	2014/15	2015/16	2016/17	2017/18	2018/19	2019/2020	2020/2021	2021/22	2022/23	2023/24
TE Maintenance	R3.00	R3.00	R3.00	R3.00	R3.00	R3.00	R3.00	R3.00	R3.00	R3.00
PRV Maintenance	R1.00	R1.00	R1.00	R1.00	R1.00	R1.00	R1.00	R1.00	R1.00	R1.00
Education and Awareness Campaigns	R1.18	R1.24	R1.30	R1.37	R1.43	R1.51	R1.58	R1.66	R1.74	R1.74
Leak Repair	R0.14	R0.91	R1.58	R1.20	R1.78	R1.95	R1.88	R2.10	R0.96	R0.96
Leak Detection Projects	R0.57	R3.63	R6.32	R4.81	R7.12	R7.79	R7.51	R8.39	R3.85	R3.85
Treated Effluent Meter reading	R0.21	R0.22	R0.23	R0.24	R0.26	R0.27	R0.28	R0.30	R0.31	R0.33
Community Engagement	R1.91	R2.01	R2.11	R2.22	R2.33	R2.44	R2.57	R2.69	R2.83	R2.97
Customer Satisfaction Survey	R0.69	R0.72	R0.76	R0.79	R0.83	R0.88	R0.92	R0.96	R1.01	R1.06
Retrofit and leak repair	R3.15	R3.30	R3.47	R3.64	R3.83	R4.02	R4.22	R4.43	R4.65	R4.65
Logger installation	R3.00	R5.00	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00
Zone Metering	R2.00	R4.00	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00

Figure 23: Interventions required for sustaining low water losses (CCT, 2015b)

Table 23: Cape Town Active Leakage Control Progress (Basholo, 2016)

Description	Highbury	Highbury Park	Wesbank	Mfuleni	Du noon	Pella	Totals
Period of detection	2013	2013	2014	2014/15	2015	2015	
Length of mains (km)	20.39	15.34	22.91	58.62	32.08		149.34
No. of properties	1259	942	3204	8441	3025		16872
No. of leaks located	46	12	77	215	40	23	413
Status of leak repairs	Leaks repaired	Leaks repaired	Leaks repaired	In planning[1]	In planning[1]	In planning[1]	Generally not repaired

[1] As of 2016, these leaks detected between 2014 and 2015 were not repaired yet in these areas

4.1.3.3. Response time and quality of repairs

The City of Cape Town has a limited number of water distribution network repair teams available and therefore has developed a tiered pipeline failure response system to prioritise repairs. For example large pipe bursts and leaks are prioritized over smaller bursts and leaks (CCT, 2016b). Table 24 is the City of Cape Town's pipeline leak assessment and repair response matrix.

The First Level Response consists of one trained official who assesses a reported leak and gathers preliminary information for assigning the repair to the correct size response team as per guidelines on the response matrix (Rodkin, 2012). The more challenging repairs have a higher resource allocation and therefore receive a higher priority and shorter response times. The city repairs most large bursts within one hour to prevent losing large volumes of water (CCT, 2016b). Smaller leaks take longer to repair due to these resource constraints. However if very minor repairs are required the First Level Response official will do the repairs immediately even if the burst or leak is not large (Rodkin, 2012).

Table 24: Mains Leak Repairs Response Levels (Basholo, 2016)

Response Levels	Response Team Scope
1st Level Response	Determine: • repair responsibility (Municipal or Private) • repair level, resources required • shut-off area • shut-off sequence, recharge sequence • re-charge main on completion • Monitor Pressure Zones, daily Pressure Monitoring Charts
2nd Level Response	• Semi-skilled Supervisor/ Driver + 2 staff + 1ton LDV + tools • Effects minor repairs • Meter replacements • Repairs pipes, valves, hydrants • Rebuild hydrant boxes • Replace covers etc.
3rd Level Response	• Plumber/ Senior Foreman + 4 staff + 3ton Vehicle • Install New Connections 20mm and up • Repairs burst water mains up to 250mm
4th Level Response	• Senior Foreman, Senior Handymen, 10 Workers, Machine Operator, 5 ton crane truck with Driver • water main Replacement or new Installations • Burst main repairs above 250mm

The benefits of the response matrix are as follows:

- There's a rapid response to leakage complaints
- Ability to shut down or isolate burst mains in a short time
- Reduce risk of private damage
- Reduce risk of damage to vehicles unknowingly riding into holes caused by pipeline failures
- Reduces overtime by allocating only the necessary resources
- Minimises more bursts by scrutinising pressure zones

The pressure across an entire supply zone must be monitored in to ensure that leakage levels are reduced through leakage repairs. The 1st level response stage of the rapid response matrix ensures that the pressure is monitored in conjunction with required repairs. The second highest investment (Figure 23) for sustaining water loss reductions is the advanced water loss programme which focuses on retrofitting and leak repair projects for indigent households. Resource constraints are highlighted as threats to ensuring that all bursts reported are repaired within 48 hours.

4.1.3.4. Mains Replacement

The City of Cape Town implemented an accelerated programme to improve the replacement of water mains and is prioritising areas that experience a high incidence of bursts (CCT, 2015a). The mains replaced per year from 2007 through to 2016 are graphically depicted on Figure 24.

19.7 km of mains were replaced in 2007/08 and increased funding in 2008/09 led to the replacement of 45.8 km but the figure came down to 24.9 km for the 2009/10 financial year (CCT, 2009). The author did not find the replacement data for the 2010/11 at the time of writing. According to CCT (2015c) the total mains replaced from 2011/12 to 2015/16 was 296,121 m. This includes 90 km replaced in 2011/12 (CCT, 2012b), 70.3 km in 2012/13(CCT, 2015b), 55.4 km in 2013/14 (CCT, 2015a), 48.6 km in 2014/15 (CCT, 2015c), and 32.8 km of large diameter mains in 2015/16 (CCT, 2015c; CCT, 2017).

The City's water demand management strategy set a target of replacing 115km of mains per year which is just over 1% of the total network (CCT, 2013b). Over the 10 year period spanning 2007 to 2016, the length of mains replaced corresponds to approximately a 400 km length of pipes; which represents less than 0.5% of the total network (CTM, 2017). An estimated minimum of R 57,530,590 per year (0.4% of Current Replacement Cost of network) was budgeted for water mains replacement for the 2016/17 FY. Therefore the draft 2017/18 WSDP has emphasized that the Pipe Replacement Programme will need to receive a progressively increased budget to deal with the replacement backlog (CCT, 2017).

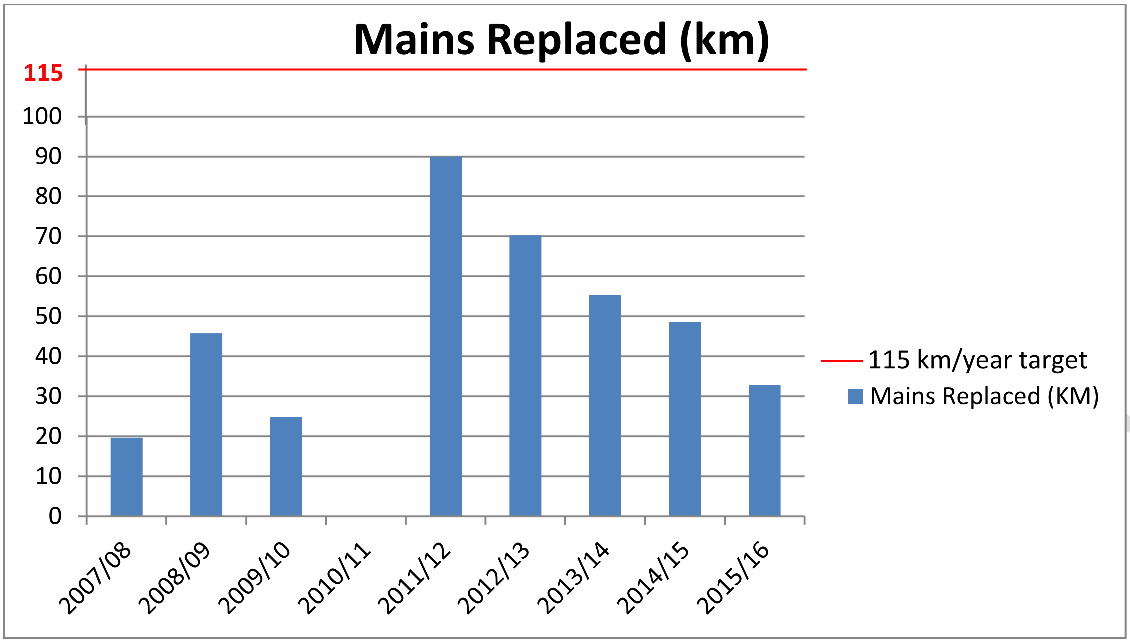


Figure 24: City of Cape Town Mains Replaced (2007 – 2016)

The WSDP has set priorities and identified areas where mains need to be replaced as well as the required implementation budgets for each year over the next five years (2017-2022). The successful implementation of the planned maintenance could be severely impacted if the actual allocations remain insufficient.

4.1.4 Performance improvement

The adopted maintenance strategies have achieved overall improvement in the condition of the network in terms of reduced number of main bursts and loss of water from the network (CCT, 2013a).

The performance summary is reviewed by looking at three metrics namely:

1. The Department of Water and Sanitation's No Drop Certification Score
2. The number of bursts on mains
3. The percentage of water physically lost compared to the water purchased

4.1.4.1. No Drop Certification

The City of Cape Town received a No Drop score of 95% in the National Department of Water and Sanitation's 2014 First Order Assessment. According to DWS (2015b) this score indicates that the city has “excellent” knowledge of its water infrastructure status, and has “established the required processes, systems and plans to manage water losses”.

The indicators used for in the No Drop assessment include an Infrastructure Leakage Index (ILI) of 2.74 and actual physical water loss percentage of 14.5%. The ILI indicates good water loss management but could be improved if there’s a business case for improving further. The No drop assessment also took into account that the city has a comprehensive Water Demand Management strategy that reflects in the IDP (DWS, 2015b).

4.1.4.2. Main bursts

The water distribution networks experienced 5237 bursts to water mains in 2008/09 compared to 6080 in 2007/08 (CCT, 2009; van Rooyen, 2011). The 2009/10 bursts however increased again to 6169 with 59 bursts per 100 km. The burst rates increased again to 63.9 bursts per 100km of piping in the 2010/11 financial year and the number of bursts also continued to increase to 6645. The number of burst mains in the first eleven months of each year has steadily decreased: 4085 in 2011/12, 3306 in 2012/13 and 3313 in 2013/14. The corresponding rate of bursts per 100 km per year is as follows: 40 in 2011/12, 32 in 2012/13 and 31 in 2013/14 (CCT, 2015a). A total of 2330 were repaired in the 2014/15 financial year and the accompanying burst rate reduced to 24 bursts per 100 km.

Table 25: City of Cape Town Burst Data Summary (2007-2015)

Year	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15
# of bursts	6080	5237	6169	6645	4085	3306	3313	2330
Bursts/ 100km	58.7[1]	50.6[1]	59	63.9	40	32	31	24

[1] Based on total length 10353 km.

Table 25 summarises the pipe burst data from 2007 to 2015. Figure 25 graphically illustrates the declining trend between 2010 and 2014; no further trending data for pipe bursts from 2015 to date was found in the publicly available subsequent reviews and annual reports of the City of Cape Town's WSDP (CCT, 2016a; CCT, 2017). As discussed in 4.1.3.4 many kilometres of mains have been replaced each year and the City of Cape Town attributes this dramatic reduction in pipe bursts to the mains replacements and pressure management (CCT, 2016b). The city set a target to reduce and maintain pipe bursts to below 10 per 100km per annum by the end of the 2012/17 period (CCT, 2015a). This target has been revised down to 15 burst/100km/year for the 2017/22 period (CCT, 2017).

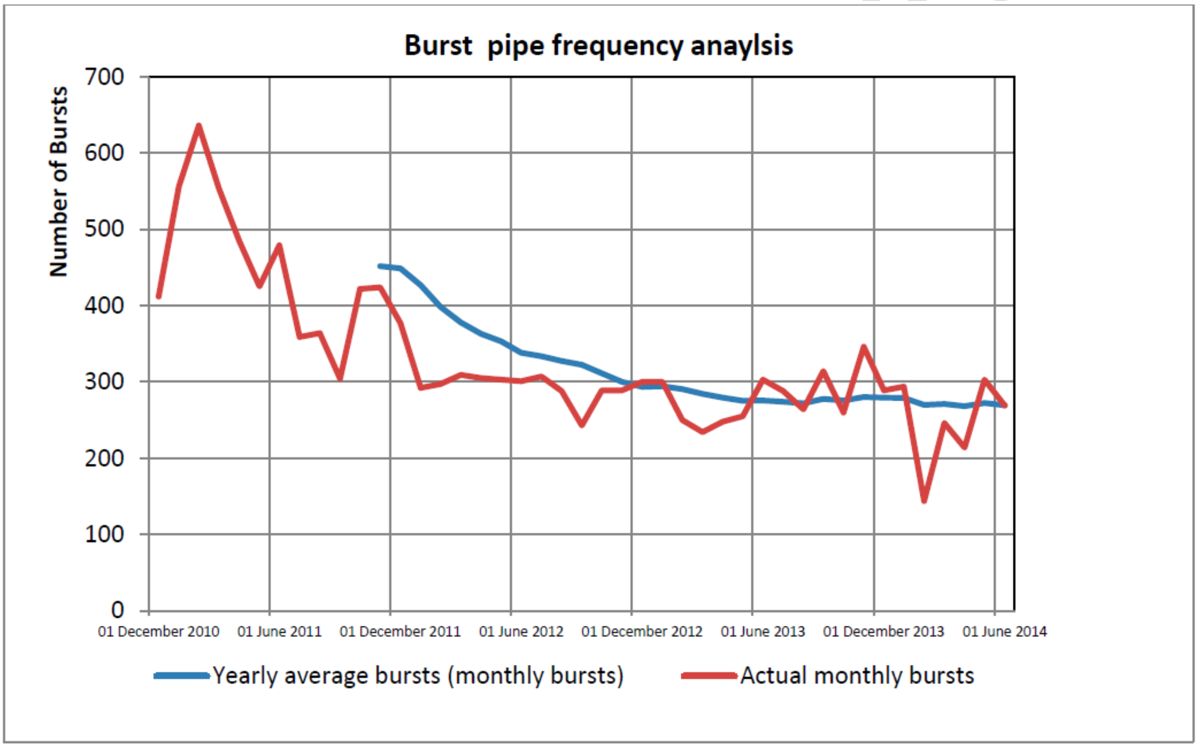


Figure 25: Burst Frequency Analysis 2010-2014 - City of Cape Town (CCT, 2015b)

4.1.4.3. Water loss

Although the burst rate has shown a downward trend in the previous section, this may not coincide with a reduction in water loss percentage. However, the City of Cape Town's data shows a similar trend for actual losses. Figure 26 displays the historic trend of the month to month ILI value for the City of Cape Town. The calculated ILI for 2013/14 year dropped to approximately 1.88. The actual water losses in percentage reached all-time lows around

15% between 2012 and 2014 (Figure 27). The improvement in leakage values coincides with the implementation timelines of the mains improvement projects, active leakage surveys and pressure management initiatives.

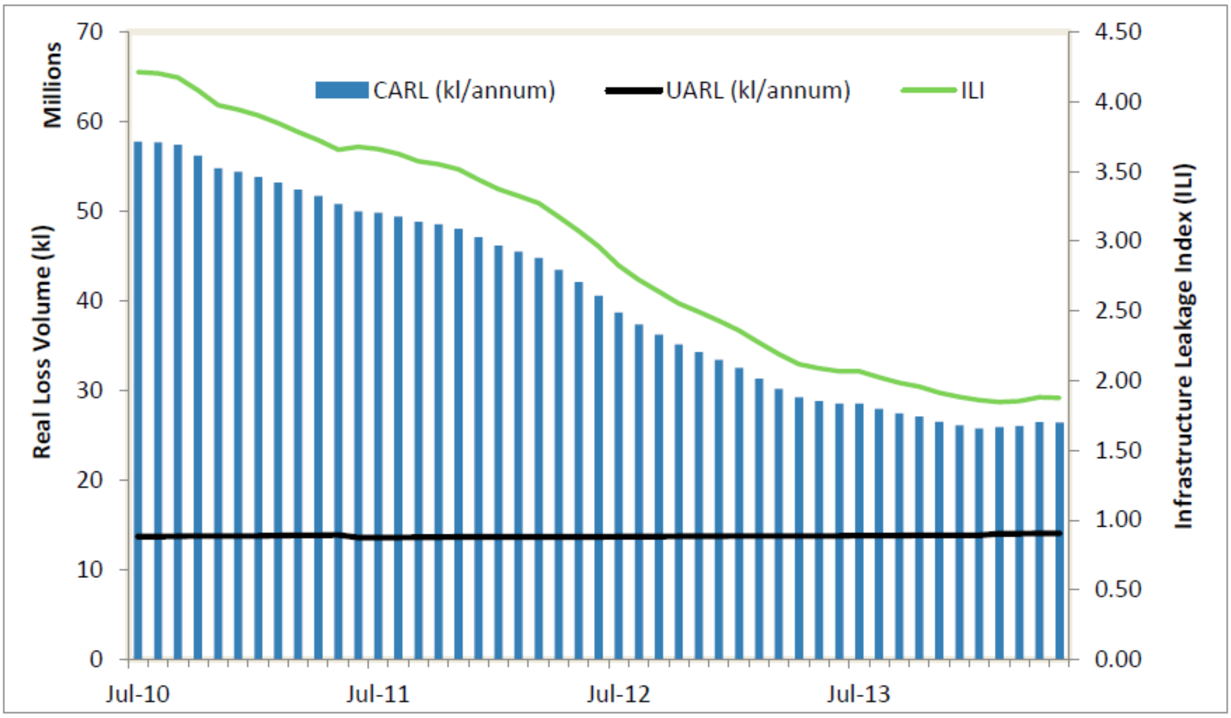
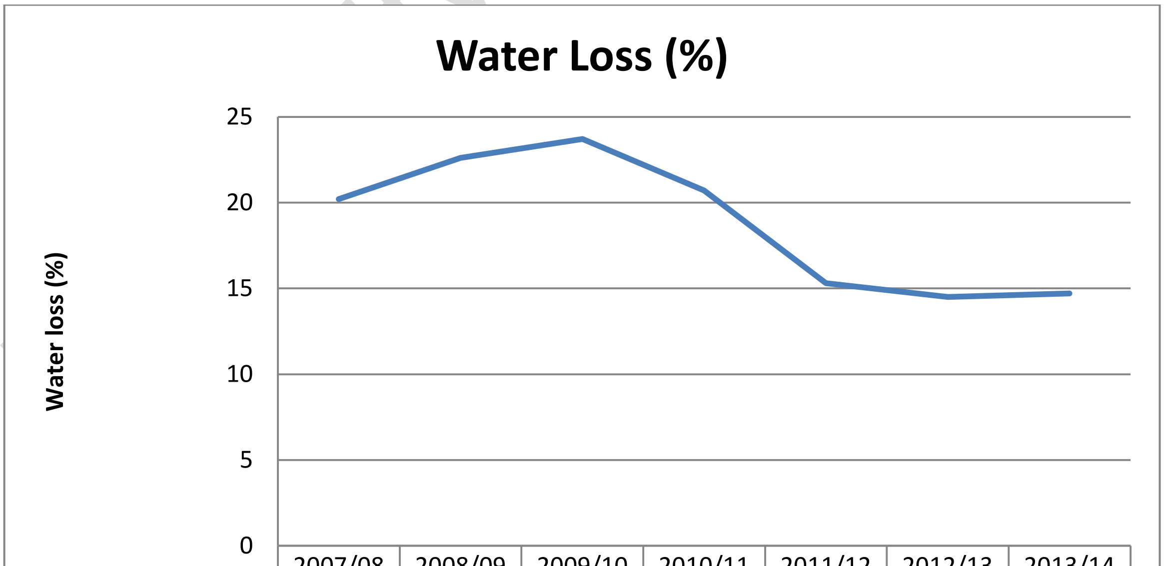


Figure 26: Infrastructure Leakage Index Trend 2010-2014- City of Cape Town (CCT, 2015b)



	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14
Water loss (%)	20.2	22.6	23.7	20.7	15.3	14.5	14.7

Figure 27: Water Loss Trend 2007-2014- City of Cape Town (Data from CCT, 2015b)

4.2 City of Johannesburg

4.2.1 Water Services Infrastructure Development Plans

4.2.1.1. Infrastructure Development Plan

The City of Johannesburg's first Integrated Development (IDP) plan was approved in 2003 after a three year cyclical developmental process (COJ, 2003). Subsequently annual IDPs were developed based on the progress and refinement of the previous year's IDP. The City of Johannesburg revised its long term strategy in 2011 and this necessitated a review of the IDP to ensure it was aligned with the city's revised focus areas (COJ, 2013). This review resulted in the 2012/16 IDP. This IDP's implementation plans were based on the following six principles (COJ, 2013):

- Eradicating Poverty
- Building and growing an inclusive economy
- Building sustainable human settlements
- Ensuring resource security and environmental sustainability
- Achieving social inclusion through support and enablement
- Promoting good governance

For the 2012/16 and 2016/21 IDPs the city adopted several priorities for achieving long term goals aligned with the above principles (COJ, 2013; COJ, 2016):

1. Economic growth, job creation, investment attraction and poverty reduction
2. Informal Economy, and SMME support
3. Green and Blue economy
4. Transforming sustainable human settlements
5. Smart city and innovation
6. Financial sustainability
7. ***Environmental sustainability and climate change***
8. Building safer communities
9. Social cohesion, community building and engaged citizenry
10. Repositioning the city of Johannesburg in the global arena

11. Good governance

The city has recognised Water Demand Side Management as one of the programs to respond to Priority 7 (Environmental sustainability and climate change) to ensure sustainability of delivering water services (COJ, 2016). Excessive water losses and ageing water distribution infrastructure are among the key factors identified under the city's financial sustainability and poor asset management strategic risk categories respectively (COJ, 2013). Table 26 summarises the main priorities for Johannesburg Water that have a direct impact to water distribution infrastructure performance.

Table 26: Johannesburg Water IDP Sub-programmes (JW, 2013a)

IDP Programme	Key outputs in relation to IDP interventions
Quality of Services	Response times of water bursts
Asset Management	Asset Management Plan
Demand Side Management	Water Conservation/Water Demand Management Plan

4.2.1.2. Water Services Development Plan

The City of Johannesburg prepared its first Water Services Development Plan (WSDP) for the 5 year term 2005-2009. The plan was developed as a sector plan of the IDP to provide overall policy framework for delivery of water services (COJ, 2005). One of the key aspects of the WSDP was the targeted reduction of water losses over the five years from 36% to 25% in order to align the city to international best practice of losses between 20 to 25%.

The WSDP addressed the development and maintenance of Water Services Infrastructure and highlights the challenges faced by Johannesburg Water with regards to keeping up with maintenance of existing and new infrastructure. The city's integrated water resources strategy is outlined and proposes water demand management strategies to address the water losses in the distribution network. The policy framework that was then subsequently adopted in 2013 to support water demand side management was the "Accelerated Water

Conservation and Demand Management Strategy". The focus areas of the strategy included (DWS, 2014b):

- Pressure management
- Water mains replacements
- Active leak detection
- Soweto Infrastructure Upgrade and Renewal Programme

These interventions are discussed in detail in section 4.2.4.

At the end of the First term (2005/09), the WSDP had not been updated by the end of 2011 according to SALGA (2011). Since the end of the First term of the WSDP there are no revisions or updates available in the public domain and the 2012/16 and 2016/21 IDPs do not reference any requirements to align the WSDP to the strategic goals of the city. According to the WSDP, JW was required to compile annual business plans to set out its strategies and plans for achieving annual targets. JW continues to develop annual business plans to date.

4.2.1.3. Johannesburg Water Business Plans

Instead of a WSDP, JW developed a business plan for the 2012/16 revised IDP that was aimed at achieving the city of Johannesburg's long term goals. The final business plan was adopted from the 2013/14 financial year and it covered the subsequent financial years until the 2016/17 financial year (JW, 2013b). This plan informs the 2012/16 IDP for the city of Johannesburg with respect to water services; it sets out the services to be delivered as well as planned improvements for the period under consideration. According to JW (2013b) the business plan is a mechanism to deliver the statutory outcomes set out by the Department of Water Affairs (DWA).

The business plan provides the extent and values (including the remaining useful lives) of water distribution assets which was not previously covered in the superseded 2005/09 WSDP. Budgeting requirements for capital investment for new infrastructure as well as maintenance expenditure for key IDP programmes aimed at improving the water distribution network. Key programmes and projects covered are similar to those covered in Water Demand Management initiative that started as part of the 2005/09 WSDP (JW, 2013b).

JW's business plan contains an organogram with the complete staffing structure and institutional arrangements. The organogram lists all the functions that enable Johannesburg Water to deliver on its mandate and objectives (JW, 2013b).

4.2.2 Asset Management Framework

JW adopted a phased approach to Asset Management (Figure 28). Johannesburg Water started its Asset Management Programme in 2007/08 by preparing a high level Infrastructure Asset Management Framework document as Phase 1 of the programme (Childs *et al*, 2013). The subsequent phases then focused on improving the infrastructure asset management programme and development of the Asset Management Plan. The framework provided an overview of the general structure of the Asset Management documents. The Phase 1 framework proposed the following key outputs:

- The first iteration of performance targets related to Asset Management
- Implementation plans for all divisions within Johannesburg Water
- Establishment of an Asset Management Division

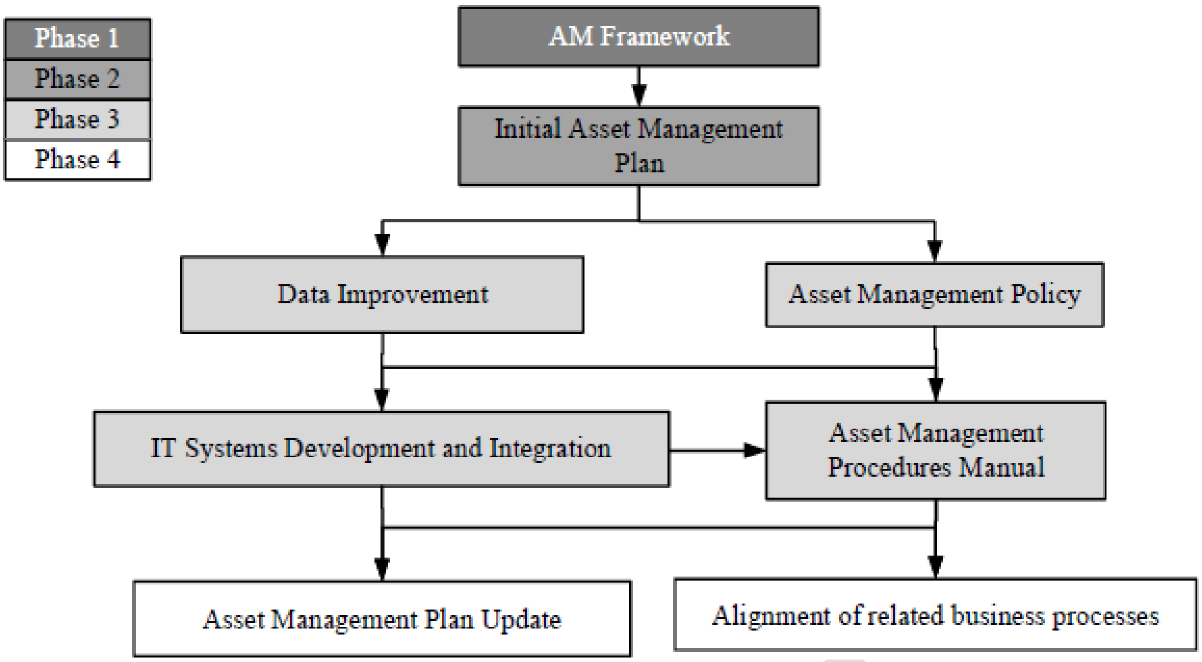


Figure 28: JW asset management improvement approach (Child's et al, 2013)

4.2.2.1. Asset Management Programme Improvement

Phase 2 of the Asset Management Programme commenced in the 2008/09 FY and the completed initial asset management plan was rolled out in the 2009/10 FY (JW, 2010). JW envisaged that the rollout and implementation would assist in reducing the frequency of water services infrastructure failures such as burst frequency and system losses.

Phase 3 of the programme focused on improving the data quality of the city's infrastructure and the exercise was done over a two year period. The exercise included reviewing of existing data sets for completeness and accuracy. For example; data on water mains bursts has been captured for the network over many years, however when the data was found to be insufficiently accurate for linking to specific pipes in the network. Field verifications found discrepancies with data captured on GIS records and led to the review of as built drawings and updates to GIS data (Childs *et al*, 2013).

In the 2011/12 FY the targets that were set for the asset management plan were achieved and 99.6% of the budget for the year was used; however the allocated budget was less than what was required to ensure effective management of the infrastructure (JW, 2012).

4.2.2.2. *Asset Management policy and strategy*

Phase 3 also covered the development of the asset management policy and strategy to give effect to the policy (Figure 29). The policy presented principles approved by the Board of Directors that Johannesburg Water would adopt (Childs *et al*, 2013). The procedures or strategy documents contain the following key Infrastructure Asset Management processes:

- Overview of guiding principles and drivers for change
- Roles and responsibilities for implementation
- Description of the key tasks
- Annual cycle of Asset Management processes
- Data structure and models
- Structure of information systems
- Templates and forms

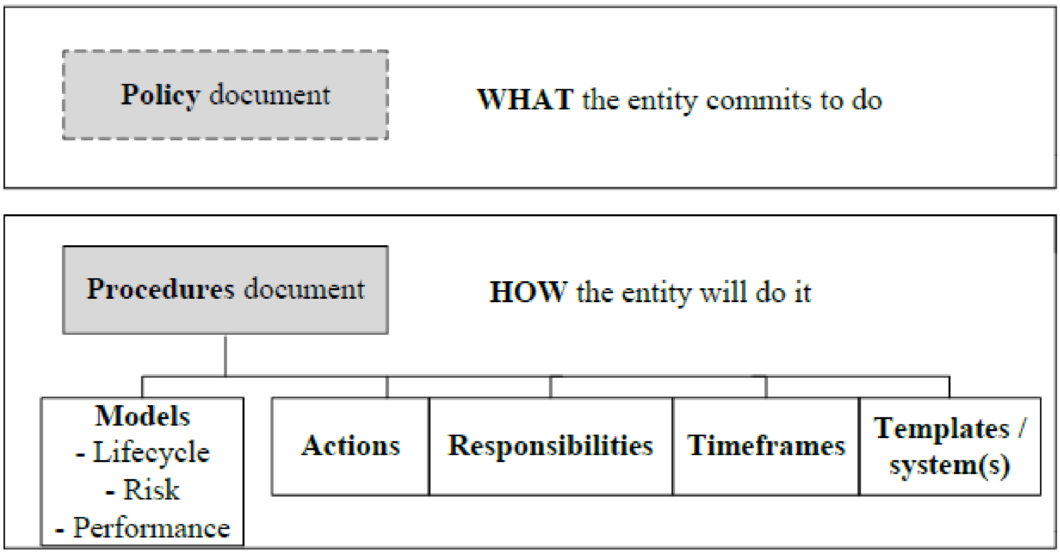


Figure 29: Asset Management policy and strategy (Childs et al, 2013)

4.2.2.3. *Final Integrated Asset Management Plan*

The Phase 4 of the Asset Management programme implementation started from 2012/13 and was completed in the 2013/14 financial year which marked the end of the development of the programme (JW, 2013b). The integrated asset management plan systems are therefore intended to be fully implemented by the end of the 2016/17 IDP term.

According to the 2014/15 business plan of JW “the Asset Management Plan has been used as a crucial tool to analyse the state, condition and competitiveness of JW’s physical assets and conditions, including the working environment and other physical factors affecting the cost of doing business and cost of producing the services”.

4.2.3 Maintenance and Rehabilitation Strategies

In the late 80s the city of Johannesburg established economic criteria for renewal and continued maintenance of mains; the criteria compared the cost of maintenance for the expected useful life with the cost of replacement of the mains (Fox & Verrier, 1991). According to Fox & Verrier (1991) this resulted in a reduction in capital expenditure on new infrastructure and stopped further deterioration of leakage rates.

According to Childs *et al* (2013) annual expenditure on the renewal of existing water infrastructure has been as low as 0.3% of its current replacement cost against a target replacement rate of 2% (JW, 2014); and this has resulted in the deterioration and increasing failure of the infrastructure. To respond to the imminent failure of ageing infrastructure the JW Infrastructure Renewal Plan (IRP) is set up to increase the infrastructure renewal rate from below 1% to 3.5% to eliminate backlogs (JW, 2017b).

The current interventions aimed at reducing water losses that JW has adopted as part of the demand management programme consist of the following:

1. Pressure Management Project
2. Soweto Infrastructure Upgrade and Renewal Project
3. Water Pipe Replacement
4. Active leakage control and the prepaid metering project

To ensure that water demand management interventions are a priority for the whole organisation JW provided training company-wide to present basic concepts of Water

Conservation and Water Demand Management (WC/WDM), network design principles, and leakage control strategies that included pressure management and pressure relieve valve maintenance (DWS, 2014b).

4.2.3.1. Pressure Management

After a series of pilot projects the city executed a full scale Pressure Management Project in 1997 and this was then completed by 1999 (McKenzie, 2014). The pressure management initiative was aimed at reducing high night time leakages and pipe bursts associated with high pressure in the system (JW, 2011a). Some of the pressure management device have however become dysfunctional over their service life due to lack of adequate maintenance (Meyer, 2015). Funds for maintenance and replacement remained inadequate until around the 2012/13 financial year (JW, 2012).

Lessons learnt from the City of Johannesburg's pressure management projects include (JW, 2011a):

- Pressure management is cost efficient in large areas; however the areas are difficult to manage.
- Pressure reducing devices should be correctly sized and maintained during operation.
- Pressure management systems to be installed at a single point of supply, and if not possible the points of supplied must not exceed three.

Where leakages were occurring the city established that high pressure increased the amount of water lost (COJ, 2005); therefore areas where further pressure management can be implemented continued to be identified by the city and the upgrading of existing systems to the latest technology was also being continuously investigated (JW, 2011a). High pressures ranging from 50 to 90 metres were identified through assessment of the network and are used a basis to prioritise new installations and upgrading of old systems (JW, 2011a; JW, 2013b).

The programme to refurbish the devices officially kicked off in March 2013 (JW, 2013a). The scope of the project was to repair all the pressure reducing valves (PRVs) operated by the City of Johannesburg (see Table 27); with a target of saving 35.8 million m^3 of water per annum. From the 1^{st} quarter of 2013 to the 3rd quarter of 2014, savings of 1.2 million m^3 per annum were achieved (JW, 2014).

The target was to service all pressure control devices operated by JW by June 2015; however, only 60% of the Pressure Control Valves were serviced by the original set date (Meyer, 2015). The following challenges were experienced in the implementation of the project:

- Small number of operational resources was allocated to the project in the initial stages.
- There were discrepancies between the GIS data and actual field situation- approximately 150 differences between existing drawings and field installations were detected.

Table 27: City of Johannesburg projected annual savings due to PRV servicing (JW, 2014)

Depot Region	Number of PRVs to be serviced	Original planned completion date	Projected savings 2013-2016 (m3/year)
Randburg	149	March 2013	3.92 million
Sandton	137	July 2014	3.6 million
Jhb Central	52	August 2014	1.4 million
Midrand	86	November 2014	2.3 million
Deep South	22	December 2014	0.6 million
Soweto	45	March 2015	1.2 million
Total	**491**		**12.9 million**

4.2.3.2. Soweto Infrastructure Upgrade Project

In 2005 the City of Johannesburg established that 83% of the total water losses were experienced in Soweto and overall demand of Soweto accounted for 30% of the water purchased by the city (COJ, 2005). To respond to these high levels of leakage Johannesburg Water initiated a water infrastructure upgrade project that was called Operation Gcin'amanzi (OGA) in 2003 for which was planned to be completed in 2007.

The project was however not completed by 2007 as planned and in 2008 it was suspended due to a court judgement (DWS, 2014b; JW, 2010). The programme was re-launched in 2010 as the Infrastructure Upgrade and Rehabilitation Programme (IURP) (JW, 2010). The aim of the programme was to reduce the amount of water that was not accounted for including water that was physically lost (JW, 2012). Most of the leakage was found to be at domestic properties (JW, 2013a).

The scope of the programme was as follows (JW, 2013b):

- Upgrading network infrastructure:
    - Replacing 200 km of steel secondary mains with uPVC pipes
    - Relocating water network from the 'midblock' to road reserve
    - Replacing corroded yard connections with HDPE pipes
- Once of repair of domestic leaks
- Prepaid meter installations
- Water use and conservation awareness campaign

According to JW (2012) the programme progressed well in the 2011/12 FY and required funding was allocated as per the 2012-2016 City of Johannesburg IDP. Significant progress was made on installation of prepaid meters and retrofitting domestic fittings; 80% of planned progress was achieved by the end of the 2015/16 financial year. 116km of secondary mains were replaced before 2008 and 50km replaced in 2013/14. According to JW (2014) this has influenced the reduction of water losses in Soweto. For the 2016/17 financial year Johannesburg Water intends to complete the Soweto IURP by finishing the remainder of the secondary mains replacement, retrofitting of domestic fittings and meter installations (JW, 2016).

4.2.3.3. Mains Replacement

In the late 1980s the City of Johannesburg used burst records to inform the replacement of water mains. Table 28 lists the number of bursts (No/100km/year) at which it was economical to replace water mains in residential areas in Johannesburg for steel and PVC mains based on the burst growth rate of the distribution network (Fox & Verrier, 1991). However, according to JW (2011b) replacement of mains was still being done on an adhoc basis until the implementation of the Water Demand Management Strategy in 2007/08. JW is now prioritising pipes according to their burst frequency and identifies the mains using a Geographic Information System (GIS) (JW, 2011a). The current target is to reduce bursts per 100 km per year to below 266 (JW, 2015a).

Table 28: Burst rates for economical mains replacement in the 1980s (Fox and Verrier, 1991)

Mains size and material	**Annual burst growth rate (%)**			
	2	**4**	**6**	**8**
100 mm steel	1020	780	580	430
150 mm steel	1120	860	640	470
110 mm uPVC	710	550	410	300
160 mm uPVC	970	750	550	410

The pipe replacement programme for water networks was kicked off in June 2008 with a target of replacing 900 km of water mains over 5 years; most of the pipes targeted for replacement are asbestos cement pipes with high burst frequencies and with a remaining useful life below 2 years (JW, 2013b). Over 5 years this target represents approximately 1.5% annual renewal of the water network. From June 2008 until June 2012 three phases of the project were completed with over 200 km of mains replaced in addition to the stand alone Soweto mains replacement project discussed in the previous sub-section (COJ, 2012):

- Phase 1 (2008/09): 72km
- Phase 2 (2009/10): 96km
- Phase 3 (2010/11- 2011/12): >18km

60 km was replaced in the 2012/13 financial year (JW, 2014); but these replacements did not reach the 900 km over the 5 years of implementation.

For the four year period from 2013 to 2017 the 900 km renewal target was re-baselined as per Table 29. Due to budget constraints the target was however revised down to 709 km in the 2015/16 Business Plan. In the 2014/15 period JW only managed to achieve 45% of the original target and a total of 321 km were replaced in the first two years of the four year period (JW, 2015a). A total of 140 km of water mains were replaced during 2015/16 period (JW, 2016).

The following is a summary of the actual replacements that were done:

- 2013/14: 182 km (including 50 km for Soweto IURP)
- 2014/15: 139 km
- 2015/16: 140
- 2016/17: year not yet ended (Revised target 105 km)

The target for this period was further revised down from 709 to about 520 in the 2015/16 Annual Report. The reduced levels of implementation resulted in an average renewal rate of approximately 1%.

Table 29: Johannesburg Water planned mains replacement from 2013-2017 (JW, 2014)

PIPE REPLACEMENT PROGRAMME SUMMARY					
Region	Length of Mains Replaced (m)				
	2013/14	**2014/15**	**2015/16**	**2016/17**	**Total**
Region A: Midrand	7 770	39 055	36 470	46 640	129 935
Region B: Sandton Alex	29 790	54 595	47 935	69 760	202 080
Region C: Randburg Roodepoort	29 151	69 210	80 214	82 685	261 260
Region D: Southdale Langlaagte	21 355	80 880	16 515	75 870	194 620
Region E: Soweto	50 000	50 000			100 000
Region F: Deep South	5 820	14 240	53 886	9 675	83 621
Total	**143 886**	**307 980**	**235 020**	**284 630**	**971 516**
Renewal Rate (%)	**1.39**	**2.70**	**2.06**	**2.57**	

In addition to funding constraints, one of the other factors cited for the poor performance of the main replacement programme was delays experienced with required environmental approvals and the issuing of water user licenses for projects in close proximity to water courses (JW, 2015a).

4.2.3.4. Active Leak Control

The leak detection and repair programme was implemented from 2008 in the formal areas of the city as an intervention stemming from the WSDP. This was an alternative to outright replacement of mains (WRC, 2007). It was setup to be an on-going programme and currently Johannesburg Water prioritizes leakage detection activities through monitoring monthly high night flows in the system (JW, 2011a). Once the priority areas are identified the detection of leaks is carried out in two phases:

- Visual surveys
- Active Leakage detection using acoustic equipment

According to JW (2011a), there are 15 Active Leak Control (ALC) teams that survey approximately 89% of the total water reticulation network annually to identify visible leaks and any network anomalies. The teams are made up of a supervisor, three operators and three assistants who are trained to carry out leak detection. JW has achieved a success rate of 80% with respect to repairing leaks and faults reported by the ALC teams (WRC, 2007). The success is also linked to the leak response times achieved by the repaired teams.

The real water loss reductions achieved are through ALC are hard to quantify, however JW is confident that this intervention plays an important role in managing invisible pipes bursts and subsequently reducing losses by finding the leaks before significant water has been lost (WRC, 2007).

4.2.3.5. *Leak Repair Response Time*

Network repairs response time is not a key water demand management intervention for City of Johannesburg however the performance of Johannesburg water and consistently improved. JW restores 95% of water bursts within 48 hours (JW, 2015b). This has been made possible by setting up a “Special Services Department” that has dedicated teams who main focus is responding to active and potential leaks (WRC, 2007).

Areas that experience a high frequency of pipe failures and main bursts may experience delayed response times that may be longer than 48 hours (JW, 2015b). According to JW (2015a) positive improvements have been made in reducing the number of bursts than are open for more than 7 days by implementing a minimum requirement for repair teams to repair three major bursts and three other network related work orders per shift.

4.2.4 Performance improvement

The City of Johannesburg has realised savings as a result of the pressure management and main replacements, and to some extent, the Active Leakage Control programme has improved the performance of the network.

4.2.4.1. *No Drop Certification*

The Johannesburg Metropolitan municipality has received a No Drop score of 84% as per 2013 Department of Water and Sanitation’s first order assessment which indicates that the city has “good” knowledge of its water infrastructure, and has established the required processes, systems and resources to monitor its water losses. The city had an ILI of 6.54 which indicates poor water loss management and this is also accompanied by a water loss percentage of 23%.

The water use efficiency in the 2013 assessment was reported as 339.8 litres per person per day against an international value of 180 litres. This figure is based on the gross volume of water used per capita including the domestic component and non-domestic water use component (DWS, 2015a). According to DWS (2015a) the high figure can be in indication of high domestic leaks and or high usage of consumers who do not understand the criticality of the scare city of water in South Africa. This indicates that the efforts of the Soweto IURP have not translated into improved water use efficiency as they had two projects targeted specifically at fixing domestic leaks as well as engaging with citizens to create awareness on water conservation.

4.2.4.2. Main bursts

The number of main bursts has shown a declining trend over the past few years:

- For the 2009/10 FY the number of mains bursts was 330.9 against a target of 354 bursts per 100/km/year (JW, 2010).
- Number of bursts for the 2010/11 FY was 277.6 against a target of 342 bursts per 100/km/year (JW, 2011b).
- Number of bursts for the 2011/12 FY was 301.4 against a target of 324 bursts per 100/km/year (JW, 2012).
- The number of bursts for the 2012/13 FY was 299 against a target of 324 bursts per 100/km/year (JW, 2013a)
- The mains replacement and pressure management projects reduced pipe bursts incidents from 35,539 in the 2012/13 FY to 32,131 in the 2014/15 FY per annum and the number of bursts experienced per 100km was 273.14 against a target of 266 (JW, 2015a). However, in the 2015/16 FY the number of bursts increased by 18.6% due to a slowdown in the pipe replacement project (JW, 2016).

Table 30 is the summary of pipe burst data from 2009 to 2016, while Figure 30 graphically illustrates the declining trend between January 2008 and January 2011; according to JW (2011b) a 90% reduction in pipe bursts was achieved between 2008 and 2011.

Table 30: Johannesburg Burst Data Summary (2009-2015)

Year	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16
Bursts/ 100km/ year	330.9	277.6	301.4	298.7	N/A[1]	273.1	302.9[2]

[1] 2013/14 Annual report was not obtainable

[2] Estimated based on total length 12581 km

Figure 30: Burst frequency analysis 2008-2011 - City of Johannesburg (JW, 2011b)

4.2.4.3. Water loss

The total water losses for the City of Johannesburg were about 36% in 2004 and the city had set a target to reduce the losses by 11% by the end of 2009; this target was contained in the 2005/09 WSDP. The target was however not reached as the rate of water loss increased by approximately 6% between 2008 and 2012; JW then subsequently concentrated their effort on reducing the rate of water loss (COJ, 2005). From 2011 there's been a marked reduction in water losses that saw the water loss percentage dropping below 25% in 2014 as illustrated by Figure 31 (Hugo, 2012; JW, 2015a; JW, 2016).

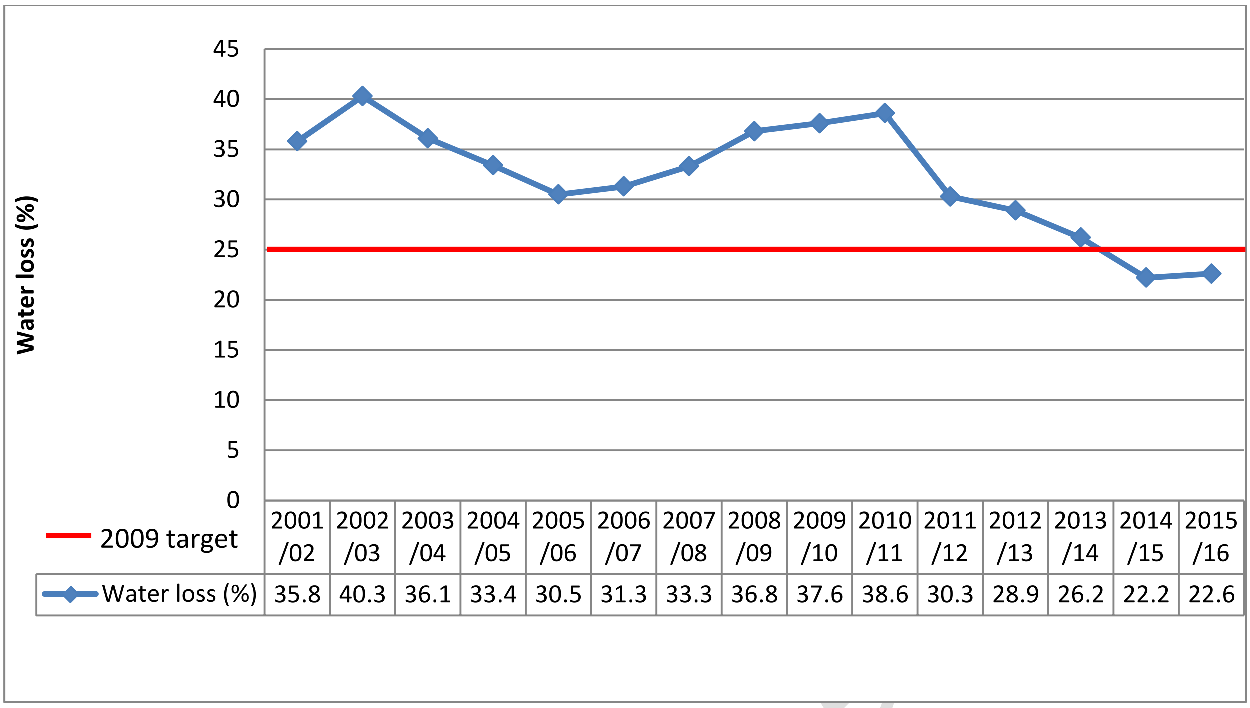


Figure 31: - City of Johannesburg Water Loss Trend 2004-2016

4.3 Enabling factors and challenges

4.3.1 Overview

The implementation of the Water Demand Management strategy for the City of Cape Town was not sustainable in the early stages of implementation due to numerous institutional challenges including the initial commitment and resources. The resources from 2003 to 2006 were significantly reduced (CCT, 2007a). Increased investment from 2007 enabled the identified maintenance strategies presented in section 4.1.4 to gain traction and these have led to a reduction in main bursts and leakage, with the exception of the Active Leakage Control project which only received resources from 2013. Sustained financing and continuous improvement of asset management processes is needed to keep the services operating at current levels and to improve performance going forward.

The performance and failure data of the City of Cape Town's water mains is the main criteria for replacement and this data doesn't take age of mains into account. Linking age of mains to failure can assist to determine the root cause of the failures and improve the estimation of the mains useful lives. JW however does take the age of mains into account and prioritises mains that are close to the end of their useful life, taking their burst frequency performance into account.

The City of Johannesburg has been slow in catching up with the mains replacement programme but is still supporting the projections. The biggest challenge is that the backlog is growing and the actual budget allocations are below 2% so this exacerbates the infrastructure performance as the useful life of infrastructure diminishes from year to year. City of Cape Town faces the same risk unless funding is increased to this level. Increased funding is therefore central to the achievement of the demand management strategy.

The City of Johannesburg's Accelerated Water Conservation and Demand Management Strategy seems to have supported the downward trend in the reduction of water losses from 2011 to 2015 (Figure 31), however in the 2015/16 FY there was a slowdown in the mains replacement programme again and it can be seen that the water losses were starting to take an upward trend. The number of bursts in the 2015/16 FY also increased (Table 30).

As discussed in section 4.1.3.4, the City of Cape Town also undertook an accelerated programme to improve the replacement of water distribution mains, but this was done about 5 years earlier than Johannesburg's accelerated strategy. And the main bursts from 2007 to 2015 have consistently dropped year on year (Table 25, Figure 25). Although there was a slight increase in the actual water lost between 2007 and 2010, the percentage has consistently dropped from 2011 to 2014. The 2013 No Drop Certification report has indicated that to improve the ILI of the city a benefit analysis would need to be undertaken. However, the continued good performance will require adequate maintenance of the old and new pressure control installations and adequate annual rehabilitation of the mains.

The City of Johannesburg's water use efficiency of 339.8 litres per person per day is higher than that of the City of Cape Town's water use efficiency of 229.6 litres per person per day. Compared to the national target of 200 litres per person per day, Johannesburg has to improve on its domestic leak repair interventions. The provisions made by the City of Cape Town from 2014 until 2024 (Figure 23) to continue investing in the retrofitting and leak repair interventions for indigent households will assist in ensuring that the levels of consumption are maintained and/or improved. The indigent leak repair intervention includes installation of water management devices control and limit water flow to domestic properties (CCT, 2015c). According to McKenzie & Wegelin (2010) inefficient water use can also be controlled through pressure management; therefore future pressure management installations can contribute to reducing excessive domestic water use and leakages. JW planned to roll out the installation of smart metres in the 2014/15 FY to improve, amongst other things, domestic property leakage and repairs (JW, 2014); however the intervention is still pending budget availability (JW, 2015b).

4.3.2 Summary

Table 31 summarises the City of Johannesburg's (COJ) and the City of Cape Town's (CCT) strategies implemented with the accompanying key drivers and threats for each strategy based on the above discussions, performance results of each city as well as best practices discussed in the literature review section.

Table 31: Enabling factors and challenges for implemented strategies

Strategies	City	Strengths (enabling factors)	Weaknesses (barriers to implementation)	Opportunities (for increasing the levels of interventions)	Threats (to the strategy)
Pipe Replacement	**CCT**	Areas with high incidents of burst are known and the replacement plan for next 5 years is captured in WSDP	Construction difficulties in built up areas and water cut off during replacement	Looking at alternative funding options for WC/WDM and ring-fencing WDM funding	Insufficient funding below 2% of the Current replacement cost of water distribution network
	COJ	Remaining useful lives of mains are known as well as the corresponding burst frequencies.	• Delays in environmental approvals • Delays in issuing water user licenses for projects close to water course	Looking at alternative funding options for WC/WDM and ring-fencing WDM funding	Insufficient funding below 2% of the Current replacement cost of water distribution network
Pressure Management	**CCT**	The pay-back period for the intervention is typically less than a year for the installations	Pressure Management cannot be used in every area especially hilly areas	Implementation of Advanced Pressure Management installations with real time monitoring systems	Insufficient maintenance budget to service Pressure Relieve Valves
	COJ	Initial PRV servicing implementation challenges are resolved. GIS data and drawings updated to reflect accurate site installations	Pressure management is cost efficient in large areas; however the areas are difficult to manage.	Scope for pressure management to be investigated in areas with inefficient use of water such as garden irrigation and high domestic leaks	Reduction of PRV servicing budgets and maintenance resources
Active Leak Detection	**CCT**	• 3 active leak detection and repair teams have been set up • Priority areas for active leak detection and	• Normal leak detection equipment cannot pick up leaks below 250 litres/hour • Current coverage	Increase amount of teams and target total coverage of network annually instead of only priority areas	Reduction or lack of Financial resources

		repair are identifies	is a small percentage of network		
	COJ	• 15 Active Leak Control (ALC) teams have been setup and survey approximately 89% of the network annually • Faults are logged and assigned a Job Card and allocated to the correct repair team	Normal leak detection equipment cannot pick up leaks below 250 litres/hour	Increase annual ALC coverage to 100% (Coverage has increased so far: 70% in 2008, 89% in 2011)	Reduction or lack of Financial resources
Response Time and Quality of Repairs	**CCT**	• A trained repair team is setup and uses a rapid response matrix to prioritize and assign repairs to the correct • There's a 24 hour hotline for reporting leaks and bursts • Most large bursts repaired within 1 hour to prevent losing large volumes of water	• Smaller leaks take longer to repair due to resource constraints while prioritizing larger bursts • Repairs on networks that are no longer viable are ineffective	• Addressing resource constraints specifically for repairing smaller leaks • Promote reporting of visible leaks by the community	• Resource constraints are highlighted as threats to ensuring that all bursts reported are repaired within 48 hours • Poor quality of repairs
	COJ	• Implementation of JW's minimum requirement of repairing 3 major bursts and 3 other distribution network errors per day	• Areas that experience a high frequency of pipe failures and main bursts may experience delayed response times that may be	• Developing and setting up more resources to repair leaks and burst within 24 hours to in order to make repairs more cost	• Poor quality of repairs • Increase in burst frequencies if performance of the mains replacement programme

		• There's a 24 hour hotline for reporting leaks and bursts • 95% of water bursts are restored within 48 hours	longer than 48 hours • Repairs on networks that are no longer viable are ineffective	efficient • Promote reporting of visible leaks by the community	declines- more resources will be required to cope with an increase in repairs required
Domestic Leak Repairs	**CCT**	The advanced water loss programme which focuses on retrofitting and leak repair projects for indigent households and funds have been allocated	• Restricted access on private properties for repairs	Investigate the feasibility of installing smart meters to improve detection of property leaks	• Reduction of funds • Vandalism • Illegal water connections
	COJ	The Soweto IURP funding has been increased to complete the remainder of the scope which includes fixing domestic leaks	Restricted access on private properties for repairs	Accelerate the roll out of the installation of smart metres to automatically detect on site domestic property leakage	• Vandalism • Illegal water connections • Funding constraints

5. CONCLUSION AND RECCOMENDATIONS

Progress made in last two decades in the development of legislative frameworks for management of public assets was analysed and discussed in the literature study. Best practices in controlling leakage and maximising asset value of water distribution networks were also reviewed to highlight critical factors that need to be implemented to achieve sustainable management of distribution networks. Finally, the effectiveness of present regulatory framework for maintenance of local water distribution infrastructure was assessed through documentary analysis of two study areas that represent the largest proportion of water distribution networks in South Africa.

The hypothesis made 3 assumptions

1. The existing regulatory framework that governs planning for maintenance of local government infrastructure as well as maintenance guidelines are not sufficient
2. Infrastructure maintenance budgeting is not aligned with international best practices
3. There are insufficient internal technical resources to implement the correct leakage control strategies

5.1 Effectiveness of legislative framework

Both study areas adopted water distribution management frameworks that are established in terms of the legislative requirements set out by the Municipal Finance Management Act (MFMA), Municipal Systems Act and the Water Services Act. Infrastructure Development Plans or Integrated Development plans (IDPs) were prepared in terms of the Municipal Systems Act respectively for the City of Cape Town and the City of Johannesburg respectively.

The sector plans for both cities were developed in terms of the Water Services Act through preparation of Water Services Development Plans (WSDPs) and the key elements of these plans were integrated into their respective IDPs. The City of Johannesburg's WSDP was however only prepared from 2005 to 2009; thereafter it was replaced by Johannesburg Water's Annual Business Plan. The key elements of the business plan are aligned with the

IDP and the progress on key interventions is reviewed annually against the five year IDP targets.

The most critical outcome of the sector plans for addressing water losses is the Water Demand Management Strategies that were rolled out by each city. They identified interventions required to curb water losses. The identified interventions were similar for both the City of Johannesburg and the City of Cape Town with the prominent once being the replacement of mains and pressure management. Both these interventions resulted performance improvements since the water demand management strategies were rolled out. The other interventions to sustain performance and to manage the existing network included Active Leakage Control (ALC) and improving repair response times. The City of Johannesburg's ALC programme is has improved over the years and is nearing full coverage of the network, while the City of Cape Town's programme was slower in gaining traction but has identified the required funding to maintain the ALC programme from 2014 until 2024.

The City of Johannesburg developed its Asset Management Plans based on the International Infrastructure Manual to align with the requirements of the MFMA. The City of Cape Town on the other hand adopted the Asset Management Improvement Framework recommended by the Guidelines for Infrastructure Asset Management in Local Government to align their infrastructure management plans with the requirements of the MFMA for developing Asset Management Plans. These guidelines are a product of the National Infrastructure Management Strategy that was kicked-off in 2006 to strengthen the regulatory framework for management and maintenance of public infrastructure.

It is therefore concluded that the 1st assumption of the Hypothesis was incorrect as the regulatory framework developments over the last 20 years have assisted the study areas in setting up the Water Services Infrastructure Management Frameworks. The mandatory annual review cycles of the IDP has also played a significant role in reviewing performance and improving the frameworks continuously.

5.2 Maintenance budgeting

Budgeting constraints for key interventions were found to be a common challenge for both the City of Cape Town and Johannesburg since the inception of the WSDPs. Johannesburg Water expressed concern that although available expenditure allocated to the asset management plan was being spent as required, the allocation was still below the required levels of funding.

The Johannesburg mains replacement programme failed to reach its target of a 1.5% renewal rate since implementation from 2008 and to date has only archived an average renewal rate of 1%. The City of Cape Town's water demand management strategy set a target of replacing 115km of mains per year which is just over 1% of the total network but only managed to replace less than 0.5%. The current financial year has budgeted 0.4% and the draft 2017/18 WSDP for Cape Town is emphasizing that the Mains Replacement Programme will need to receive a progressively increased budget to deal with the replacement backlog.

The Active Leakage Programme remained inactive for several years in the City of Cape Town as a result of lack of funds. Despite early installations of PRVs going far back as 1997 in Johannesburg, the programme to service the installations only kicked off in 2013 with a small number of resources and struggled to reach targets. In the case of the City Cape Town the installations are relatively newer and based on installation costs presented in Table 19, a rough estimate of R25 million is estimated for the current replacement cost of all the PRV installations. To meet the international maintenance benchmark an allocation of R500,000.00 per annum is required but the actual provision made is R1 million which is twice the required amount. Since this is only a projection it cannot be concluded yet if sufficient actual provision will be realised.

The international benchmark requires a replacement rate of 2% of the network infrastructure base per annum. From the reviewed information it was found that to date this level of funding has not being made available. Therefore the 2nd assumption of the Hypothesis is correct.

The confirmation provided by the findings of this study regarding under investment in maintenance budgeting as compared to international best practice indicates that legislative framework is falling short with regards to the provision of sufficient funds for maintenance. Municipalities are expected determine their own targets and there's no legislative driver that mandates the minimum maintenance spend of 2% of the CRC.

5.3 Organisational capability

The Water Demand Management strategies for both municipalities facilitated the establishment of dedicated teams to drive the leakage control interventions.

For Cape Town, the Water and Sanitation department established a dedicated Water Demand Management branch that reports to the Director of the department directly. The Director of the Water and Sanitation Department is a registered Professional Engineer with the Engineering Council of South Africa (ECSA). The Utility Directorate as a whole consists of over 200 Engineers, Technologist and Technicians; and a portion of these employees fall under the Water and Sanitation department. The Water Demand Management branch manages the water demand management interventions as follows:

- Pipe Replacement: Internal technical resources identify and prioritise mains to be replaced. The detail design of new pipelines and installation is outsourced.
- Pressure monitoring and PRV maintenance: Pressure monitoring and analysis of minimum night flows is done internally and 1st level internal repair response teams can monitor pressure zones. Although PRV maintenance is budgeted for in the WSDP, the resource plan for this programme is not addressed in the literature reviewed.
- Active Leakage Control: This is done by dedicated internal teams within the water demand management branch.
- Leak and bursts repairs: This is done by dedicated internal leak response teams within the water demand management branch.

The demand management strategy of Johannesburg Water is embedded into the Operations division that is responsible for functions that include infrastructure planning, asset management, infrastructure investments and monitoring of assets. The operations division reports directly to the Managing Director of Johannesburg Water. The outgoing Managing Director served from 2012 until 2017 and is a registered professional Civil Engineer with ECSA and the organisation is supported by over 2400 employees that include 25 professionally registered engineers, technologists and technicians. The water demand management initiatives are managed through the following resource arrangements:

- Pipe Replacement: Internal technical resources identify and prioritise mains to be replaced. The detail design of new pipelines and installation is outsourced.
- Active Leakage Control: This is done by dedicated internal teams within the operations team.
- Leak and bursts repairs: This is done through the internal Special Services Department that has dedicated teams whose main focus is responding to active and potential leak reports.
- Pressure monitoring and PRV maintenance: Pressure monitoring and analysis of minimum night flows is done internally. Maintenance of PRVs is outsourced.

The 3rd assumption of the Hypothesis is therefore not correct as both study areas have established teams to execute their identified leakage control interventions through a combination of internal and external technical resources. The leadership appointments of both study areas complies with the competence model of the *Local Government Regulations on Appointment and Conditions of Employment of Senior Managers* that requires Infrastructure/Technical Services Directors to be in possession of qualifications accredited by ECSA as well as be registered as professionals with ECSA.

5.4 Recommendations for further research

Although the Hypotheses of this study was tested on two metropolitan municipalities that represent a large proportion of water usage in the country; the findings are not necessarily a representation of challenges or successes experienced in smaller municipalities. These municipalities are subjected to different socio-political factors and funding arrangements.

The underinvestment in maintenance funding by the two metropolitan municipalities assessed in this study however raises concerns since these municipalities have better funding, technical resources and service cost recovery mechanisms compared to rural municipalities. It can then be assumed that rural municipalities are significantly underperforming with regards to budget allocations.

Further research is therefore recommended to assess the adoption of legislative frameworks developed over the last 20 years in smaller municipalities and quantity what challenges may be present in implementing these frameworks to develop appropriate leakage control and maintenance strategies.

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